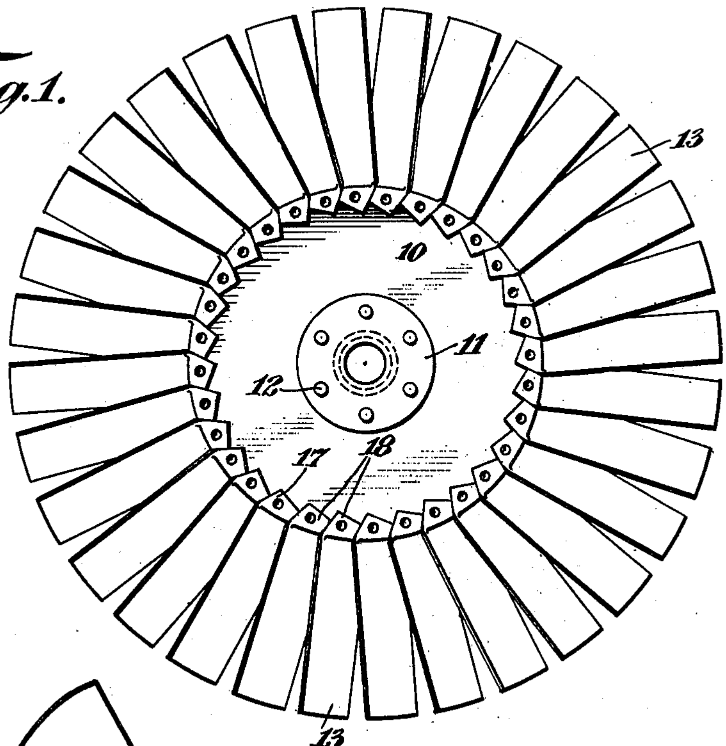
Aug. 19, 1930. G. DE BOTHEZAT 1,773,349

FAN

Filed Aug. 7, 1926 2 Sheets-Sheet 1

Fig. 1.



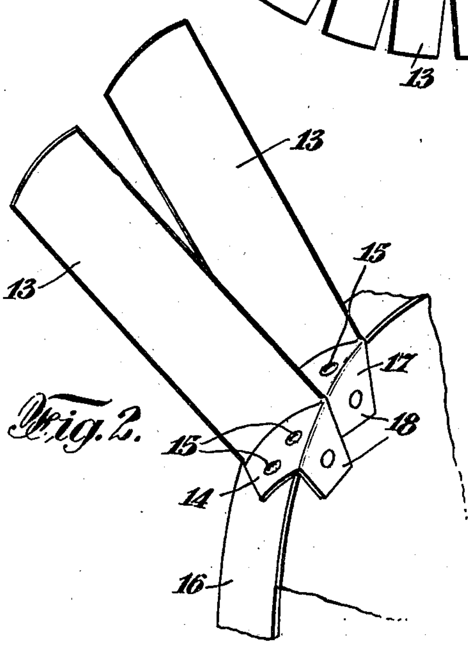


Fig. 2.

Fig. 3.

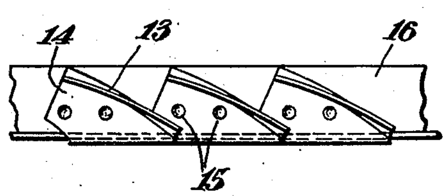


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Fig. 4.

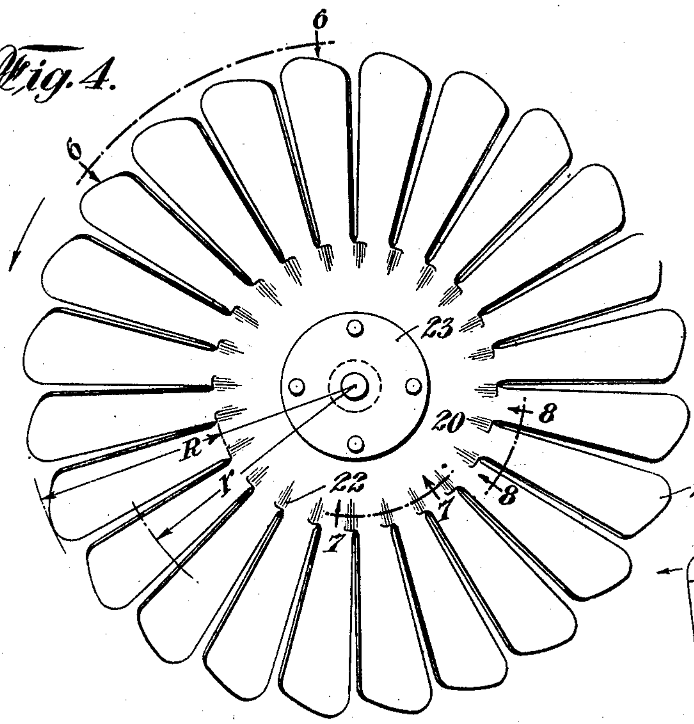

Fig. 9.

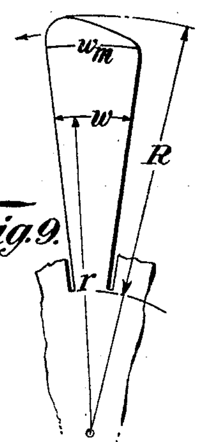

Fig. 5.

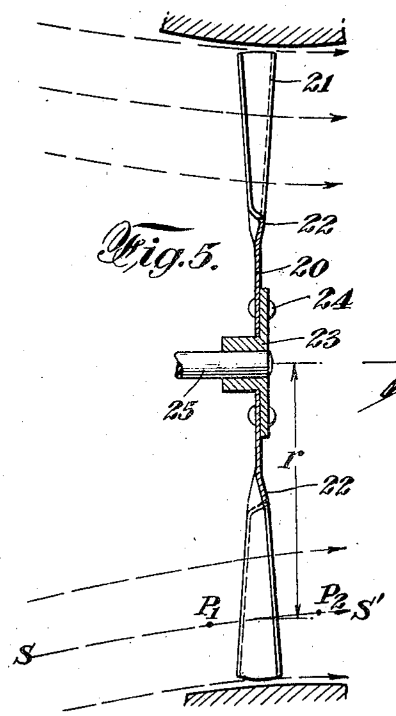

Fig. 7.

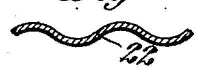

Fig. 8.

Fig. 6.

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1,773,349

UNITED STATES PATENT OFFICE

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Application filed August 7, 1926. Serial No. 127,819.

My invention relates to rotary fans and more particularly to fans of the disk type.

The object of my invention is to provide an efficient fan of the disk type for forcing the air in a generally axial direction and capable of developing high static pressures.

In disk fans of the prior art it has been usual to design and mount each fan blade individually with little or no regard to the actual behavior of the air currents and without reference to any conjoint action between the blades, and these prior fans are therefore not adapted to produce effective pressure against resistance. An object of my invention is to avoid objectionable waste of energy and to attain a maximum effectiveness in the application of the rotary energy of the fan to the movement of the air and the development of pressure overcoming resistance to the air flow.

In the fan of my invention, the blades are formed and arranged to cooperate together to move the air along smooth lines of flow and to receive the air between opposite surfaces of the blades so shaped and spaced as to give a maximum effectiveness in developing pressure against resistance, that is to develop a relatively high static pressure between the opposite sides of the fan.

Further objects and advantages of my invention will be apparent by reference to the following specification and drawings, in which

Fig. 1 is a plan view of a fan constructed in accordance with my invention.

Fig. 2 is a perspective view of the means for assembling the individual blades with the disk portion of the fan.

Fig. 3 is a development of the blades of the fan.

Fig. 4 is a plan view of a modification embodying the invention.

Fig. 5 is a sectional view of the fan shown in Fig. 4 and illustrating the mounting of the fan in a casing or channel.

Fig. 6 is a development of the blades shown in Fig. 4.

Figs. 7 and 8 are sections on lines 7—7 and 8—8 of Fig. 4, and

Fig. 9 is a detailed elevation of a blade.

In the embodiment of my invention shown in Figs. 1, 2 and 3, a flat disk or boss 10 is provided with a central hub 11 attached thereto by means of rivets or bolts 12. Parallel sided blades 13 are provided with extensions 14 welded at 15 to a ring 16 having the same outer diameter as the disk 10 and extending at right angles thereto. The blades 13 are unshrouded, being attached to the ring and spaced to provide open spaces at their tips when viewed in a plane perpendicular to the axis of the fan as shown in Fig. 1. Extensions 14 are provided with sections 17 bent over the edge of the ring 16 and welded or otherwise attached to the disk 10 at 18. The attaching of the section 17 to the disk 10 provides a securing means for attaching the ring 16 to the disk 10. The blades are diagonal to the plane of the disk 10 and are curved as shown in Fig. 3.

In the embodiment of my invention illustrated in Figs. 4 to 9 inclusive, the fan F is provided with a disk 20, from which extends in a radial direction blades 21. The blades 21 are corrugated at 22 where they merge into the disk 20 so as to provide a rigid connection to overcome any strain on the blades, which is greatest at this section of the fan. The fan is stamped and die-pressed out of a single piece of sheet metal and can be mounted on a fan hub 23 by means of screws or rivets 24. A rotating shaft 25 provides a rotating means for the fan. In Fig. 5 the fan is shown in a casing or channel where in practice it is usually confined so as to develop a difference in pressure on its opposite sides, as distinguished from free delivery. While the volume delivered by the fan will tend to increase under free delivery, and as conditions of free delivery are approached, my fan is particularly adapted to maintain efficiency with increase in static pressure. As a consequence, the power absorbed at constant speed is substantially the same throughout the entire range from free delivery when there is a minimum resistance to no delivery when the flow is blocked off and there is a maximum resistance.

I have discovered that the efficiency of the disk fan depends primarily on five features, which are:

A. Width ratio;
B. Blade spacing;
C. Blade angle;
D. Aspect ratio, and
E. The size of the boss or disk from the center to the inner portions of the blades,

and for efficient results the numerical values of these quantities should lie within certain limits.

A. The "width ratio" is the ratio of the width of the blades measured at any point to the circuference through the point at which the width is measured. Thus in the drawings Fig. 9, w is the width of the blade, r is the radius of the circle at which the width is measured, and n is the number of blades, and the

$$\text{Width ratio} = \frac{nw}{2\pi r}$$

The quantities r and w are not measured at or to the extreme tip of the blade.

B. If all the blades of the fan are cut by a cylinder of radius r having for its axis the axis of the fan, a development of the blades will be as shown in Fig. 6, and we have

$$\text{Blade spacing} = \frac{h}{w}$$

in which

h = the perpendicular distance between the chords of two consecutive blade sections.
w = the width of the blade.

C. The "blade angle" is the angle of the blade to the plane of rotation, for example, the angle b, Fig. 6, in which the arrow a indicates the direction of movement and the plane of rotation.

D. The "aspect ratio" is the ratio of the length of the blade (from the tip to the boss) to its greatest width.

$$\text{Aspect ratio} = \frac{R}{W_m}$$

in which

R =total length of blade, and
W_m=maximum width of blade.

E. The size of the boss or disk is to be considered as a certain proportion of the total fan diameter.

In the course of extended investigation, theoretically and practically, it has been found that to obtain high efficiency the width ratio should be not less than 0.8 or more than 1.2 approximately, the blade angle b should be not less than 15° nor more than 45°, the aspect ratio should be not less than 2.5 and may be much higher, and the blade spacing not less than ½ with vanes as shown in Fig. 6. The blade angle may be constant or variable from one end of the blade to the other. When the blade angle varies its minimum and maximum value should be within the limits mentioned. With the stated limits of width ratio and aspect ratio the blades turn out to be so spaced as to be not less than fifteen in number.

To illustrate the motion of the air through the fan, we will take, for example, stream line S, S′, which crosses the disk area at a distance r from its axis. The fan by its rotation produces a suction which creates the motion of the air from S to S′ (Fig. 5). From the point S on the stream line remote from the front of the fan to a point P_1 just in front of the fan the velocity of the air increases and the pressure decreases. For any stream line we can write, assuming the air does not encounter any resistance

$$P_0 = P^1 + \frac{\delta_1 v_1^2}{2} \text{ or } P_1 = P_0 - \frac{\delta_1 v_1^2}{2}$$

in which

p_0=air pressure (static pressure) at S.
p_1=air pressure at P_1.
v_1=velocity at P_1.
δ_1=air density at P_1.

If on its path from S to P_1 the air encounters resistance then the air pressure at P_1 will be decreased.

The air passing from P_1 to P_2 on the same stream line and behind the disk area of the fan, the actual component of the air velocity (that is, the component of the air velocity taken along the fan axis) can only vary slightly because the area available for the flow of air just in front of the fan and just behind is practically identical. The air, however, passing from P_1 to P_2 acquires a rotational motion behind the fan, which rotational motion constitutes a loss for the ventilation phenomena. At point P_2, therefore, the air velocity has practically the same actual component v_1 as at point P_1, and as a direct consequence of the momentum theorem for the passage of the air from P_1 to P_2 the air pressure will take a larger value at P_2 than at P_1 because the fan impels a motion to the air in a direction from S to S′. We can then write

$$P_2 - P_1 = \Delta P$$

in which

p_2=air pressure at P_2.
Δp=increase in air pressure due to the passage of the air through the disk area of the fan.

Substituting for p_1 its value found above the air pressure at P_2 is equal to

$$P_2 = P_0 - \frac{\delta v_1^2}{2} + \Delta P$$

The pressure p_2 beyond the fan will, therefore, only be larger than p_0 if

$$\Delta P - \frac{\delta v_1^2}{2} > 0$$

Assuming p_s to be the difference in pressure, we can then write

$$P_s = \Delta P - \frac{\delta v_1^2}{2}$$

in which

p_s = the pressure step furnished by a fan at the distance r from its axis.

The pressure step p_s which can be obtained along any stream line, such as S, S′ by the passage of the air through the disk area of the fan and at the distance r from its axis is directly proportional to the square of the linear velocity of the fan blades at that distance r. For finding the pressure step p_s we can write

$$P_s = kr^2\Omega^2$$

in which

Ω = the angular veolcity of fan rotation
$r\Omega$ = the linear velocity

k = the coefficient depending upon the shape, dimensions and settings of the fan blades.

By careful investigation it has been found that there is a limited maximum value of the coefficient k which for convenience will be designated k_m which can not be exceeded. The greatest pressure step that can be furnished by a disk fan at a distance r from its axis is equal to

$$P_s = k_m r^2 \Omega^2$$

Therefore, as a direct consequence from the above formula, it is shown that for a disk fan having blades of such shape and setting that the pressure coefficient k would have a constant value along the blades, the pressure step will increase from the fan axis to the blade tips as the square of the distance from the axis. The smallest pressure step furnished by the blades of the fan will determine the pressure differences that a fan can maintain. Thus disk fans with almost constant pressure step along the blades will actually constitute the rational type of disk pressure fan. Considering a fan with blades of such shape and setting that the pressure step coefficient k has its greatest possible value k_m, then a fan rotating with a given angular velocity Ω, and which must furnish a given pressure step p_s, the fan disk or boss must necessarily have its radius equal or greater than the value furnished by the relation

$$P_s = kmr^2\Omega^2 \text{ or } r = \Omega\sqrt{\frac{P_s}{km}}$$

The investigation conducted along the lines here discussed has shown that a disk fan can only furnish a static pressure of some value with efficiency when the diameter of its disk or boss is made at least equal or greater than approximately 0.4 of the fan diameter. With such proportioning of the disk or boss the pressure obtainable at the disk or boss is already only about 15% of which can be obtainable at the blade tips. Therefore, the greater static pressure to be obtained with a given angular velocity the greater must be the fan disk or boss. A fan with a disk or boss less than approximately 0.4 of the fan diameter cannot furnish at the disk or boss a pressure step of the same order of magnitude as at its tips and the air delivered by the outer portions of the blades at higher pressure circulates backwards at the disk or boss of the fan. In a fan furnishing the same pressure step from boss to tips, the coefficient k_m must have its maximum value at the boss and is progressively decreasing towards the tips, so that in passing from tips toward the boss the shape of the blade should be changed in such a way to have k_m increase from tip to boss in order to have pressure constant.

It follows that beginning from the boss the blades must have the proper shape and settings. In fans where the blades are simply secured to a flat boss and then twisted to the proper setting there will always be a section from the boss to the point where the blade has its proper setting where no pressure step will be created and the air will leak backwards during the operation of the fan. When the boss is formed with a diameter approximately 0.4 the fan diameter pressures can be obtained to force the air forward against resistance, the characteristics of the blading being maintained within the limitations above set forth.

For an example of the foregoing principles of my invention it has been found that a fan of 18″ diameter with a boss or disk of 9″ diameter rotated at the relatively low speed of 1150 R. P. M. has developed ⅓″ static pressure when delivering 1500 cubic feet per minute. The power absorbed by the fan is only about ⅛ H. P., which indicates the high efficiency of fans constructed in accordance with my invention. This is, as far as known to me, the most efficient fan ever produced.

It is to be noted that fans constructed in accordance with my invention will operate at low speeds as well as high speeds, that is, pressure will be developed at low or high speeds, the pressure, of course, increasing with increase of speed.

Rotation of the fan of my invention creates a suction and the air is drawn to it in an axial direction. The air upon passing through the fan acquires in addition to its axial motion a rotational motion given to it by the fan. The air forced through the fan is a smooth flow in an axial direction with a rotational motion in all parts of the flow and is free from irregular and cross currents. The flow as it leaves the fan takes the form of a rotating mass with substantially equal axial pressures forcing the flow, and any obstruction placed within the flow will not tend to make the flow deflect backwards because any deflection of the flow at any pressure is offset by another section of the flow of equal pressure.

This case is a continuation in part of my co-pending prior application Serial No. 11,624, filed Feb. 26, 1925.

I claim:

1. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having a boss diameter of substantially 0.4 of the overall fan diameter, a width ratio between 0.8 to 1.2, a blade angle between 15° and 45°, and an aspect ratio of 2.5 or over.

2. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having a boss diameter of substantially 0.4 of the overall fan diameter, a width ratio between 0.8 and 1.2, a blade angle between 15° and 45°, and an aspect ratio of 2.5 or over, and a blade spacing of one half or more.

3. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the oppoiste sides of the fan and overcome resistances in the path of the air stream, said fan having a boss diameter approximately 0.4 of the fan diameter such that the pressure obtainable at the boss is at least 15% of the pressure obtainable at the blade tips, a blade angle between 15° and 45°, and an aspect ratio such that the length of each blade from hub to tip is substantially greater than the width of each blade from entrance edge to discharge edge, and a number of blades at least 15.

4. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having a disk ratio, a blade angle, an aspect ratio and blade spacing of approximately the following values: disk ratio 0.4 the overall fan diameter, width ratio 1; blade angle 25°; aspect ratio 2.5 and blade spacing one half or more.

5. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having blades so formed and set with relation to each other that the blade spacing is not less than one-half and the pressure co-efficient at the root of the blade is at least equal the pressure co-efficient at the tip of the blade, the diameter of the boss of the fan being such that the pressure obtainable at the boss is at least 15% of the pressure obtainable at the blade tips, said fan having a width ratio from .8 to 1.2 approximately, and a blade angle between 15° and 45° approximately.

6. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having blades so formed and set with relation to each other that the blade spacing is not less than one-half and the pressure co-efficient at the root of the blade is at least equal the pressure co-efficient at the tip of the blade, the diameter of the boss of the fan being such that the pressure obtainable at the boss is at least 15% of the pressure obtainable at the blade tips, said fan having a width ratio from .8 to 1.2 approximately, a blade angle between 15° and 45° approximately, and an aspect ratio of approximately 2.5 or more.

7. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having blades so formed and set with relation to each other that the blade spacing is not less than one-half and the pressure co-efficient at the root of the blade is at least equal the pressure co-efficient at the tip of the blade, the diameter of the boss of the fan being such that the pressure obtainable at the boss is at least 15% of the pressure obtainable at the blade tips, said fan having a width ratio from .8 to 1.2 approximately, and a blade angle between 15° and 45° approximately, said fan having at least 20 blades.

8. A disk fan adapted for installation in connection with an opening or conduit to re-

ceive power from a shaft and force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and to overcome resistances in the path of the air stream, said fan having a disk diameter of 0.4 of the fan diameter and blade spacing not less than one-half so that the pressure at the hub is a substantial proportion of the pressure at the blade tips, and with the blades formed and spaced to give dynamic impulses to the air sufficiently frequently to develop and maintain a static pressure of at least one third inch and to deliver air at the rate of more than three thousand cubic feet per minute for each one-third horse power received from the shaft.

9. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and to overcome resistances in the path of the air stream, said fan having a disk diameter of 0.4 of the fan diameter and blade spacing not less than one-half so that the pressure at the hub is a substantial proportion of the pressure at the blade tips, and with the blades formed and spaced to give dynamic impulses to the air sufficiently frequently to develop and maintain a static pressure of at least one-third inch and to deliver air at the rate of more than three thousand cubic feet per minute for each one-third horsepower received from the shaft, so that the efficiency is greater than 50%, the said blades being adapted to impart to said air a velocity of at least one half the average linear velocity of the blades.

10. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and to overcome resistances in the path of the air stream, the said fan having a disk diameter of 0.4 of the fan diameter and blade spacing not less than one-half so that the pressure at the hub is a substantial proportion of the pressure at the blade tips, and with at least 15 blades formed and spaced to give dynamic impulses to the air sufficiently frequently to efficiently develop and maintain a static pressure of at least one third inch, said blades being adapted to impart a velocity to the air at least one half the average linear velocity of the blades so as to deliver air at the rate of more than three thousand cubic feet per minute for each one third horse power received from the shaft so that the efficiency is greater than 50%.

11. In a disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft, the combination with a central hub or disk of substantially .4 the overall diameter, of a series of not less than 15 blades projecting from the periphery of said hub or disk, and formed and spaced to have a width ratio between .8 and 1.2 and a blade angle between 15° and 45° and to deliver air substantially parallel to the axis of the fan, and to force said air against a counter pressure and to give dynamic impulses to the air sufficiently frequently to efficiently develop and maintain a static pressure of at least one third inch, so that the power received from the shaft is converted by the rotation of the fan blades mainly into the energy imparted to the delivered air.

12. A disk fan as set forth in claim 1 in which the blades are of substantially constant width from hub to tip.

13. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having blades of substantially the same width from hub to tip and formed and set with relation to each other to have a width ratio between .8 and 1.2 and a blade angle between 15° and 45° and to overlap at their inner portions near the hub when viewed in a direction along the axis with a gradual decrease in the overlapping from the hub outward so that at their outer ends the blades are non-overlapping, said blades being adapted to develop and maintain a static pressure of at least one third inch, and to deliver air at the rate of more than three thousand cubic feet per minute for each one third horse power received from the shaft so that the efficiency is greater than 50%.

14. A disk fan of claim 13 in which each blade is warped between hub and tip so as to be more nearly normal to the axis at the tip than at the hub.

15. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having blades aerofoil shaped so as to reduce the drag of the blades and of substantially greater length than width so as to have an aspect ratio greater than 2.5, the diameter of said hub or disk being 0.4 of the fan diameter such that the pressure obtainable at the boss is a substantial proportion of the pressure obtainable at the blade tips so that the blades are adapted to maintain a static pressure of at least one third inch and to deliver air at the rate of more than three thousand cubic feet per minute for each one third horse power received from the shaft so that the efficiency is greater than 50%.

16. A disk fan adapted for installation in

connection with an opening or conduit to receive power from a shaft and force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having blades aerofoil shaped so as to reduce the drag of the blades and of substantially greater length than width so as to have an aspect ratio greater than 2.5, and warped between the hub and tip so as to be more nearly normal to the axis at the tip than at the hub, the diameter of said hub or disk being 0.4 of the fan diameter such that the pressure obtainable at the boss is a substantial proportion of the pressure obtainable at the blade tips so that the blades are adapted to maintain a static pressure of at least one third inch and to deliver air at the rate of more than three thousand cubic feet per minute for each one third horse power received from the shaft.

17. A disk fan adapted for installation in connection with an opening or conduit to receive power from a shaft and to force air in a generally axial direction and to produce static pressure between the opposite sides of the fan and overcome resistances in the path of the air stream, said fan having blades of substantially greater length than width and a width ratio between 0.8 and 1.2 and a blade width at any point substantially greater than the perpendicular distance between the blades at said point, and a boss diameter substantially 0.4 of the overall fan diameter, said blades being formed from a single sheet so as to be integrally connected together at their inner ends and bent at an angle to the plane of the boss and tapered inwardly so as to have a greater width toward their outer ends.

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