Aug. 19, 1941. M. F. DOWELL 2,253,066

FAN

Filed Dec. 29, 1938 2 Sheets-Sheet 1

Fig. 1.

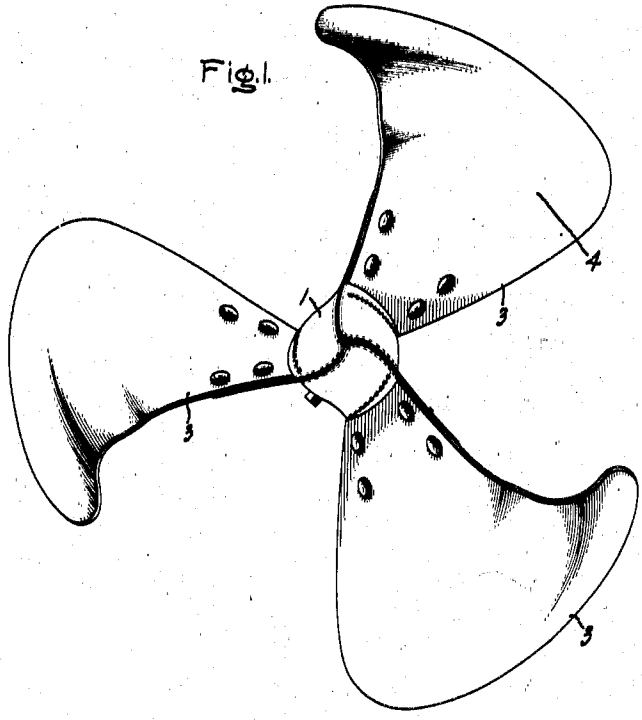

Fig. 2.

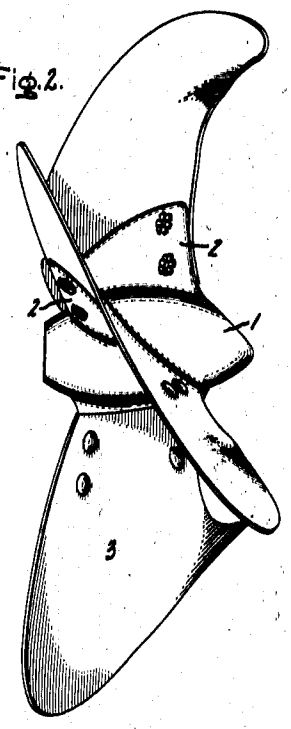

Fig. 3.

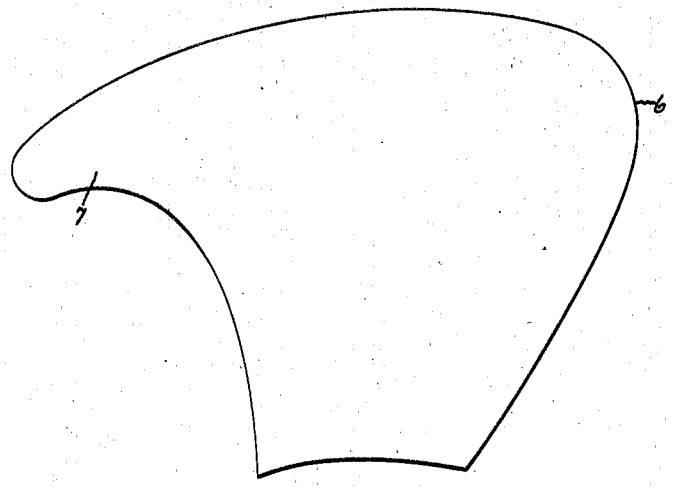

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Fig. 4.

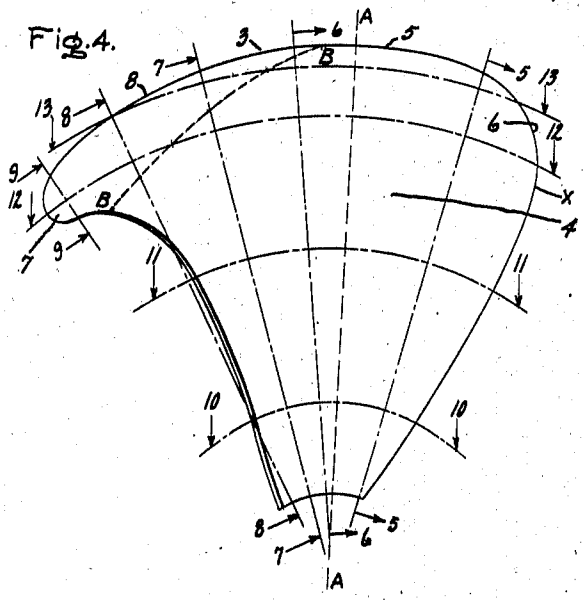


Fig. 5.

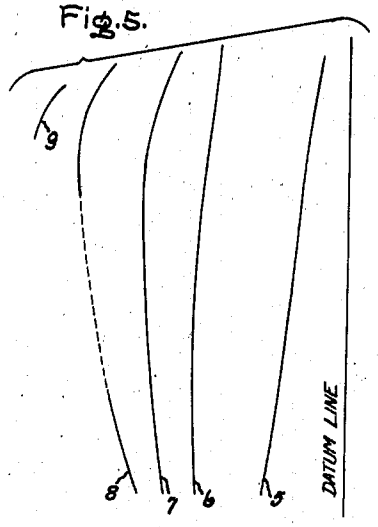
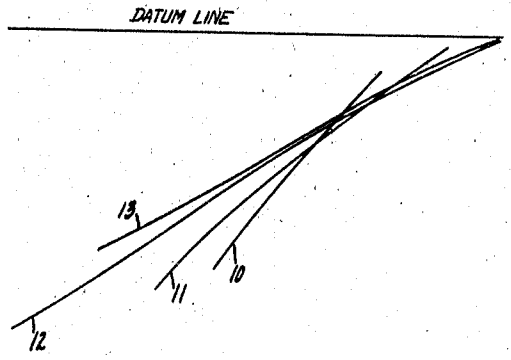


Fig. 6.



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Patented Aug. 19, 1941 2,253,066

UNITED STATES PATENT OFFICE

2,253,066

FAN

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Application December 29, 1938, Serial No. 248,275

8 Claims. (Cl. 170—159)

The present invention relates to propeller type fan blades suitable for use in free air fans, such as desk or wall fans. Such fans are frequently used in homes and offices where noise would be objectionable.

In fans of this type the air flows in different paths and at different speeds across the front or pressure and the rear or vacuum faces of the blades. From another aspect, the front and rear faces may be called, respectively, the higher and lower pressure faces. At the outer periphery there is turbulence in the air which is most pronounced at the trailing tip end of the blades on the rear or vacuum side. By the use of smoke streams and a stroboscope, it can be observed that at the peripheral edge of the fan blades a thin sheet or layer of air flows over from the pressure side to the vacuum side to form a whirling or vortexial eddy that flows along the rear side of the blades toward the trailing tips. This is commonly known as the "tip vortex."

The noise due to the agitation of the air primarily results from the separation from the blade surface of the boundary layers of the streams of air flowing across the pressure and vacuum sides of the blades, from the impact due to the joining of these streams beyond the trailing ends of the blades, and from the interference and partial impact of the tip vortexes with the main air stream or with the air stream moved by a succeeding blade. In the region of the tip vortex, the more troublesome sources of noise originate.

The object of my invention is to provide an improved fan blade construction which will decrease the noise from these sources and for a consideration of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto.

In the accompanying drawings, Fig. 1 is a front elevation of a fan embodying my invention; Fig. 2 is an edge elevation of the fan; Fig. 3 is a plan view of the blank from which the fan blade is made; Fig. 4 is a front elevation of one of the fan blades; Fig. 5 is a diagrammatic view showing the blade shape along radial lines 5—5, 6—6, 7—7, 8—8, and 9—9, respectively, of Fig. 4 with reference to a vertical plane passing through the leading end X of the fan blade; and Fig. 6 is a diagrammatic view showing the blade shape along arcuate lines 10—10, 11—11, 12—12, and 13—13, respectively, of Fig. 4 with respect to the same vertical plane.

Referring to the drawings, there is shown a fan having a hub 1, adapted to be secured to a shaft, having arms 2 projecting therefrom to each of which are secured a fan blade 3. Three fan blades are shown. A greater or less number may be used. The main body of each of the fan blades is roughly of segmental shape and occupies substantially one-sixth of the full disk area of the fan. In other words, the projected area of all of the blades is of the order of one-half of the full disk area of the fan. In the fan illustrated, the projected area of the blades is 46% of the full disk area. The projected area of the main body of the blades may vary from 40% to 70% of the full disk area. The leading ends 4, that is, the part of the blades to the right of line A—A in Fig. 4, are roughly flat or plane surfaces. The peripheral edges 5 of the leading ends are substantially arcuate and the leading edges 6 are rounded slightly. The trailing ends, that is the part to the left of line A—A in Fig. 4, are provided with tips 7 at the peripheral edge which project circumferentially through an angle equal substantially to one-fourth of the angular extent of the main body of the fan blades. The angular extent of the tips 7 may vary from one-third to one-eighth of the angular extent of the main body of the blades. As the width of the blades increases, the projection of the tips, expressed as a fraction of the angular extent of the main body of the blades, may be less. The tip projection may be expressed as of the order of one-fourth of the angular extent of the main body of the blades. The portions of the trailing ends radially inward from the tips are curved slightly forward with respect to the direction of air flow toward the trailing edges. (See 11, in Fig. 6.) The peripheral edge 8 of each trailing end has a decreasing radial extent so that it corresponds substantially to the shape of the flow line of the air passing along the rear side of the blade.

The trailing tip 7 and the adjacent portion of the peripheral edge of the blade are bent radially backward with respect to the direction of air flow perpendicular to the blade, along line B—B of Fig. 4, a line decreasing in radial extent toward the trailing end of the blade which follows the general path of air flow across the front side of the blade. The backwardly bent portion increases in radial width toward the tip, starting with a radial width of zero at a point on the peripheral edge of the blade slightly to the left of line A—A and increasing to the width of the trailing tip 7 at the trailing end of the blade when it joins and smoothly merges into the tip.

The amount of backward bending also increases toward the tip. The curvature on the rear surface of the tip bends backward as regards the direction of air flow, being roughly similar to the curvature of the tip vortex on the rear side of the blade. The curvature of the remaining part of the backwardly bent portion is such that it merges smoothly into the main body of the blade. From one aspect the backwardly bent or curved portion of the blade can be described as substantially triangular with the apex of the triangle at the periphery of the blade and the base of the triangle merging into the tip. The purpose of the backwardly bent portion is to prevent separation of the tip vortex or eddy from the rear side of the blade. An air stream is said to break away or separate when its boundary layer, the layer in contact with the blade surface, leaves the blade contour. This phenomenon can be observed by introducing smoke streams into the air. Separation is accompanied by an increase in noise. The increase in width of the backwardly bent portion corresponds with the increase in diameter of the eddy as it nears the trailing end. The increase in backward bending toward the tip compensates for the decreased tendency of the larger diameter of the eddy to follow the blade contour. While not necessary, the narrower part of the backwardly bent portion may have a smaller radius of curvature to more closely correspond to the radius of curvature of the tip eddy. In applicant's construction the tip eddy or vortex follows closely the contour of the rear side of the blade (i. e. it does not separate) and is guided into the main air stream in such a manner as to cause a minimum of disturbance. From one aspect, the curvature of the backwardly bent portion can be described as that of a segment of a truncated cone having a curved axis extending along a flow line along the rear side of the blade. The net result is that the peripheral edge of the trailing end of the blade extends radially inward by an amount which increases toward the ends of the trailing tips. In other words, the trailing end of the peripheral edge has a decreasing radial extent. The purpose of this is to allow the air flow filaments that enter at the peripheral edge 5 on the vacuum side to have long smooth flow paths in this tip region, thus minimizing separation from this vacuum side of the fan blades and allowing the tip vortex to be guided into the main air stream in such a manner that there will be a minimum of interference or a prevention of the impact of the tip vortex upon the front or pressure side of the following fan blade.

The trailing tips 7 have a radial extent of the order of one-fourth of the radial extent of the fan blades. The radial extent of the tips decreases toward the ends, or, in other words, decreases as the backward bending increases.

As shown in Fig. 6, the pitch of the fan blades is a maximum at the center (see 10, in Fig. 6) and decreases substantially radially outward toward the peripheral edge. This is for the purpose of increasing the work done by the fan blades at the center. In the center, the rotational velocity of the fan blades is less, and accordingly, a greater pitch is necessary to move the air. At lines 10—10 and 11—11 in Fig. 4 the pitch gradually increases from the leading to the trailing edge. Along lines 12—12 and 13—13 the pitch increases gradually throughout the leading end of the blade and through the first part of the trailing end of the blade and then decreases gradually throughout the trailing tip. The air does not flow across the blades along concentric circular arcs. It flows along paths extending radially inward from the leading toward the trailing end. The blade shape is such that the pitch of the blade surface along the paths of air flow on the vacuum side of the blades increases gradually throughout the whole length of the paths providing paths of substantially uniform acceleration in an axial direction. The net result is that the air is given in so far as possible a substantially uniform thrust per unit of surface area of each blade. The decrease in pitch toward and throughout the trailing tip is for the purpose of preventing the air from leaving or separating from the blade surface at the trailing end of the blade. In effect the tip eddy is eased into the air stream gradually and at such an angle that it does not strike the front side of the following blade.

Due to the backward bending at the peripheral edge of the trailing tip of the blade, this portion of the blade has a gradually decreasing pitch which decreases the thrust exerted on the air by the front side and the suction exerted on the air by the rear side of the blade. The purpose of this is to keep the tip vortex in contact with the rear side of the blade.

The air stream propelled by the fan is made up of air streams acted upon by the fan blades and air entrained by these streams. For the purpose of decreasing noise, it is desirable that the blades be wide so that the projected area will occupy as much as possible of the full disk area of the fan. This prevents interference between the air streams acted upon by the separate blades and allows the paths of air flow to be relatively long and smooth thus reducing separation on the vacuum side of the blades. However, an excess of length or improperly located surfaces increases the "friction drag" of the propeller elements, and accordingly, is one factor in causing a decrease in the velocity efficiency of the fan. The noise decreases rapidly as the projected area of the portions of the blades in the ring occupying the outer quarter of the blade circle increases from a low value to about 50% of the area of the ring. Above about 50%, the noise decreases at a slower rate. In the present construction the projected area of the blades in the outer quarter of the radial length is substantially 50%. It may vary from 45% to 90%. The blades are in effect wide at the periphery due to the trailing tips 7 and narrow throughout the remaining portion. The wide peripheral portion, the portion which is most effective in moving air due to its higher peripheral velocity, is relatively wide and accordingly is effective in reducing the noise. The relatively narrow inner portion, which is less effective in moving air due to its lower velocity, offers less obstruction to the entraining of air in or near the central portion of the fan and decreases the rotational component in this central region. The fan, accordingly, has the advantages of a wide blade fan without the resultant loss of efficiency due to the obstruction offered to the entraining of air, and to the rotation of the air at the center.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In a free air fan, a blade having a trailing tip extending circumferentially from the periphery of the main body of the blade, said tip having a backward curvature as regards the direction of air flow perpendicular to the blade sur-

face, and the periphery of the main body of the blades having a backwardly curved portion increasing in radial width toward and merging into the tip.

2. In a free air fan, a blade having a trailing tip extending circumferentially from the periphery of the main body of the blade, said tip having a backward curvature as regards the direction of air flow perpendicular to the blade surface, and the periphery of the main body of the blade having a backwardly curved substantially triangular portion with the apex of the triangle at the periphery of the blade and the base of the triangle merging into the tip.

3. In a free air fan, a blade having its periphery decreasing in radial extent toward the trailing end and having a portion at its trailing periphery curved backward as regards the direction of air flow perpendicular to the blade surface, said backwardly curved portion increasing in radial width toward the trailing end.

4. In a free air fan, a blade having the peripheral edge portion at the trailing end curved backward as regards the direction of air flow perpendicular to the blade, said backwardly curved portion starting at the periphery of the blade and increasing in radial width toward the trailing end.

5. In a free air fan, a blade having its periphery decreasing in radial extent toward the trailing end and terminating in a trailing tip extending circumferentially a distance of the order of one quarter of the angular extent of the main body of the blade, said tip and the adjacent peripheral portion of the blade having a backward curvature as regards the direction of air flow perpendicular to the blade surface.

6. A free air fan having a hub and blades carried thereby, said blades having the main body thereof of segmental shape with a trailing tip extending circumferentially therefrom at the periphery a distance of the order of one quarter the angular extent of the main body of the blades, the tip having a pitch gradually decreasing toward its end whereby the tip vortex is eased into the main air stream.

7. A free air fan having a hub and blades carried thereby, said blades having the main body thereof increasing in pitch from the leading toward the trailing edge and having a trailing tip extending circumferentially therefrom at the periphery a distance of the order of one quarter the angular extent of the main body of the blades, the tip having a pitch gradually decreasing toward its end whereby the tip vortex is eased into the main air stream.

8. A free air fan having a hub and blades carried thereby, said blades having the main body thereof of segmental shape with a trailing tip extending circumferentially therefrom at the periphery a distance of the order of one quarter the angular extent of the main body of the blades, the tip having a decreasing pitch and a backward curvature as regards the direction of air flow perpendicular to the blade surface.

MILLARD F. DOWELL.