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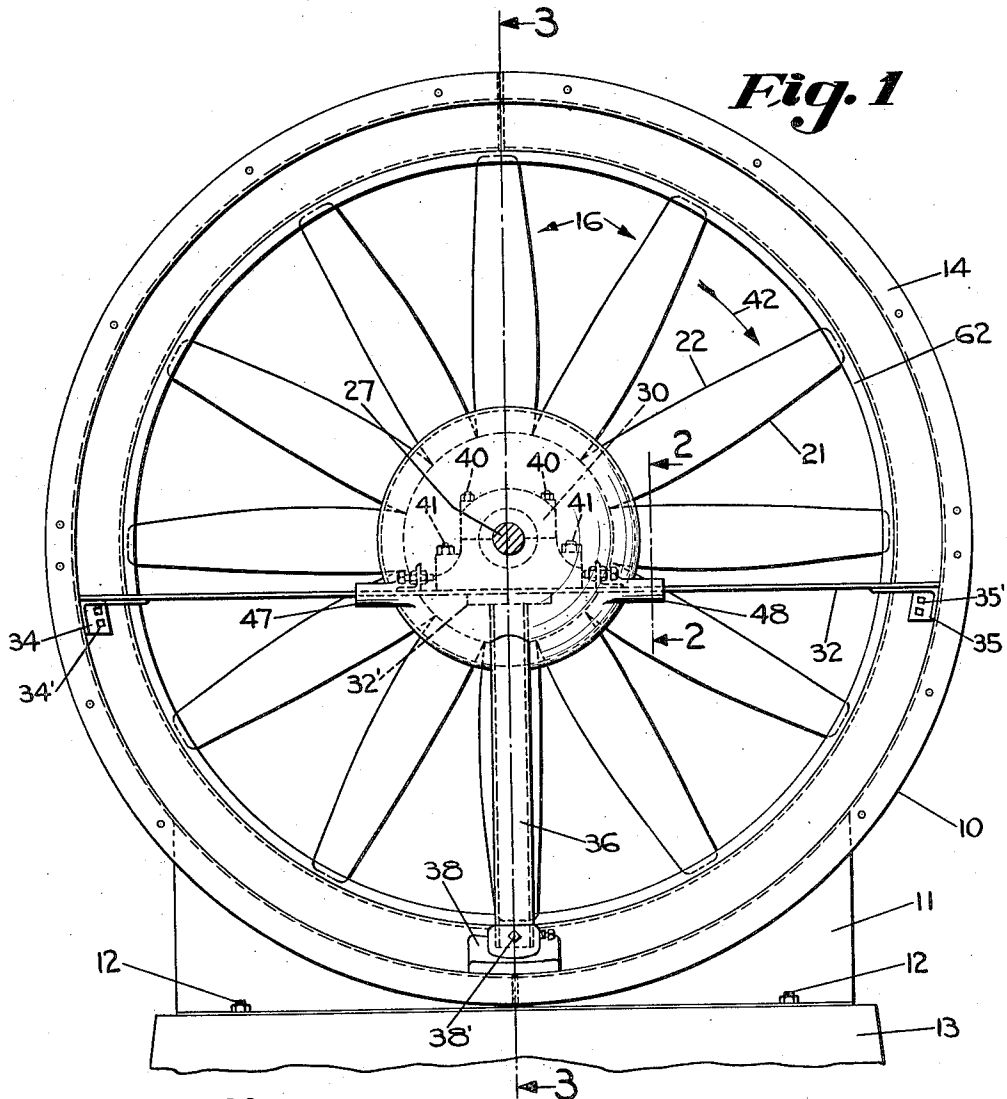
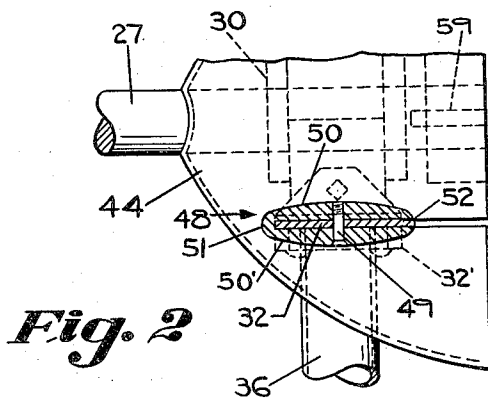
W. J. MONTGOMERY

2,027,745

VENTILATOR

Filed Sept. 13, 1933

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

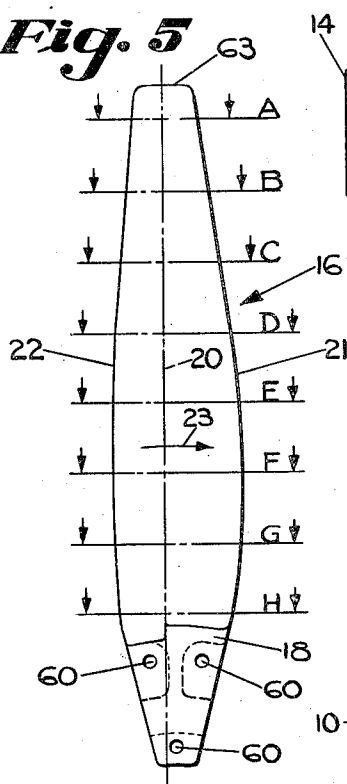
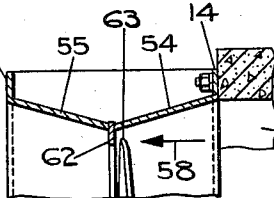
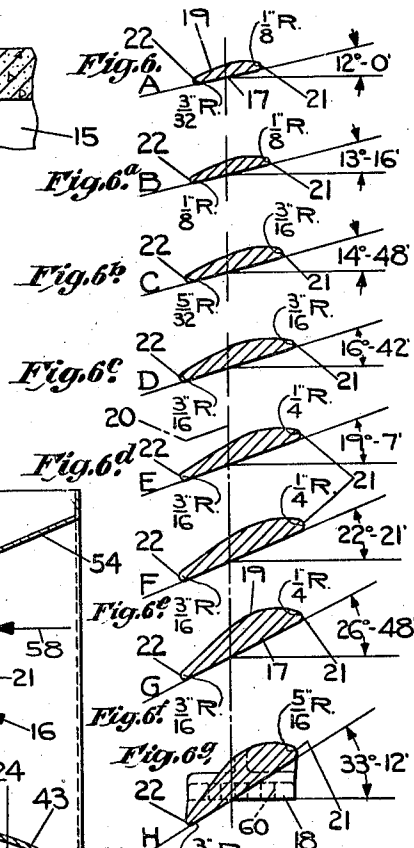
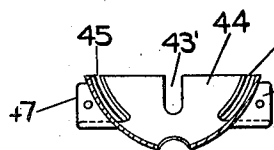
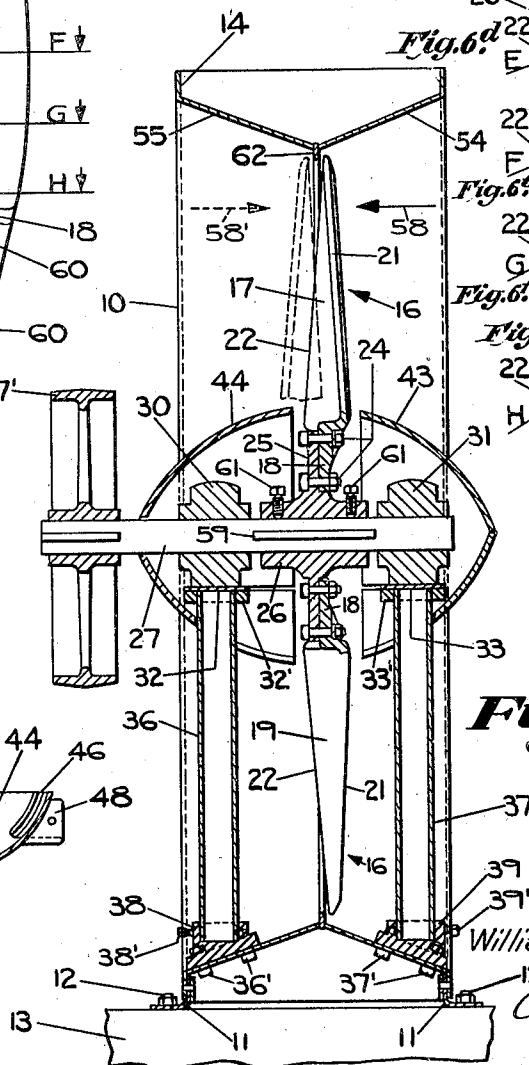


Fig. 3

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UNITED STATES PATENT OFFICE

2,027,745

VENTILATOR

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Application September 13, 1933, Serial No. 689,293

6 Claims. (Cl. 230—120)

By invention relates to ventilators of the rotary fan type and one of its objects is to provide improved and efficient mechanism for directing the flow of air without contraction of flow and to make the full cross-sectional area of the pas-
 5 sageway effective in a more efficient manner.

Another object of the invention is the provision of an annular inlet and an annular outlet respectively diverging to and converging from the plane of rotation of the fan, with an inwardly projecting lip or annulus adjacent to the tips of the fan blades between such inlet and outlet.

A further object of the invention is the provision of aerofoil blade sections for a rotary fan in which the pitch angle of each aerofoil section varies for each increment along the length of the blade section in accordance with a constant pitch diameter ratio. More particularly it is the object of the present invention to increase the efficiency of a rotary fan by combining means for controlling the flow of the air through the fan with aerofoil sections each of which has compression and suction surfaces of gradually decreasing area radially outward and in which the pitch angles vary for each increment of space radially along the length of each section in accordance with a predetermined pitch-diameter ratio so as to produce a uniform pressure over the entire area of the opening through the ventilator to effect a uniform flow of air volume over such area.

Other objects of the invention will appear hereinafter, the novel features and combinations being set forth in the appended claims.

In the accompanying drawings

Fig. 1 is an elevational view of a ventilator embodying my improvements;

Fig. 2 is a sectional elevation taken on the line 2—2 of Fig. 1 looking in the direction of the arrows;

Fig. 3 is a sectional elevation taken on the line 3—3 of Fig. 1 looking in the direction of the arrows, with a pulley added;

Fig. 4 is a detail of a portion of Fig. 3;

Fig. 5 is an elevational view of one of the removable aerofoil propeller blade sections;

Figs. 6A to 6H, inclusive, show by means of sections taken on the lines A to H, respectively, of Fig. 5, the shapes and contours of both sides of the aerofoil sections shown in Fig. 5; and

Fig. 7 is a sectional plan view of the lower portion of one of the hollow deflectors at the central portion of the fan structure shown in Figs. 1 and 3.

The fan casing 10 is mounted on the spaced-apart plates 11, 11 which are bolted at 12, 12 to the concrete foundation 13. The casing 10

may be provided with annular flanges 14, 14 at its periphery to facilitate mounting in the arc-shaped recesses in the upright plates 11, 11 and the securing of the casing 10 to the mouth of the duct 15 of a mine. Such duct may be of concrete in the form of a tunnel connected to the usual ventilating passageways in a coal mine although I wish it be understood that my improvements may have a general application.

To form the rotary fan I have found by experiment that the selection of approximately two thirds of the outer portions of the aeroplane propeller blades extending from the outermost tips toward the axis of rotation and the mounting of such aerofoil sections 16, 16 as shown in the accompanying drawings, greatly increases the efficiency over that obtained in other ventilating fan structures in use for ventilation of coal mines. But to obtain maximum efficiency each aerofoil section is warped to give it a predetermined pitch angle at various cross-sections or increments along the length of the blade radially outward.

As shown in Figs. 6A to 6H, inclusive, the warping of the flatter side 17 of each aerofoil section 16 varies from 12° at the tip A to 33° 12' at the section H near the hub extension 18. Intermediate these extremes the pitch angles vary as shown by Figs. 6B to 6G, inclusive these being sectional views on the corresponding section lines of Fig. 5.

The formula for determination of the pitch angles for each increment of blade used in the rotary fan is obtained by letting

P=pitch in inches for each blade; that is, the distance through which the air is forced by the blade parallel to the axis of rotation for each complete rotation of the blade.

R=radius in inches of each increment; that is, the radius from the axis of rotation of the fan to the cross-section lines indicated in Fig. 5.

θ =pitch angle for each increment.

Then

$$\frac{P}{2\pi R} = \tan \theta$$

The pitch-diameter ratio

$$\left(\frac{P}{D}\right)$$

is desired to be constant at approximately 64% for various sizes of rotary fans.

As determined by experiment the following table is that for fans of maximum efficiency in which each blade is so warped that its pitch

angle varies for each increment of space along the length of the blade according to the above-noted formula:

Diameter	Pitch	$\frac{P}{D}$
3'	1' 11"	.639
4'	2' 7"	.646
5'	3' 2 1/4"	.642
6'	3' 10"	.639
7'	4' 6"	.643
8'	5' 2"	.646
9'	6' 10"	.648
10'	6' 5"	.642
		Average .643.

The diameter D above mentioned is the diameter of the fan; that is, the diameter of the circle circumscribed by the tips of the blades thereof during a complete revolution. It is therefore a constant for any given fan. The pitch of any given fan is also a constant. For example, as seen from the above table, the pitch for a three foot (3') fan is constant at approximately one foot and eleven inches (1'11"), and the pitch for a ten foot (10') fan is constant at approximately six feet five inches (6'5").

On that side 19 of the aerofoil section 16 opposite the warped side 17 the surface 19 is provided at each increment with a definite and predetermined curvature as shown in Fig. 6, so as to provide increased thickness of material to the right of the radial line 20, a short distance back from the leading edge 21 of the propeller blade. The radii of the curvatures at the leading edge 21 decrease radially outward as shown in Fig. 6. The trailing edge 22 is relatively thin.

It should be understood that when the aerofoil sections are mounted in a fan structure they are rotated in the direction of the arrow 23 of Fig. 5 for greatest efficiency in a suction fan or in a blower.

As shown in Fig. 3 the aerofoil sections 16 are secured by means of bolts 24 to the disc 25, the hub 26 of which is keyed to the shaft 27. A pulley 27' may be operatively connected to the shaft 27.

The shaft 27 is journaled in the bearings 30, 31 mounted on bar cross-beams 32, 33 the ends of which are secured at 34, 35 to the casing 10 by bolts 34', 35'. Pipe pedestals 36, 37 have their lower ends secured at 38, 39 to the lower portion of the casing 10 and their upper ends to the lower sides of the bar cross-beams 32, 33, intermediate the ends of the latter by means of the rings 32', 33'. As shown in Figs. 1 and 3 the vertical pedestals 36 and 37 are directly under the journal bearings 30 and 31.

As shown at 40, 41 the journal bearings 30, 31 are detachable from the upper sides of the bars 32, 33 so that the entire fan structure including all of the aerofoil sections shown in Fig. 1 is removable for repair, or for reversal from the full line position to the dotted line position shown in Fig. 3. If the shaft 27 is rotated anti-clockwise as viewed in the direction of the arrow 58 of Fig. 3, so that the fan blades move in the direction of the arrow 42 of Fig. 1, the flow of air will be inward as indicated by the arrow 58 in Fig. 3, the fan then operating as a blower to force air into the duct to which the fan structure is connected.

The use of a single disc 25 in connection with removable propeller blades enables me to mount such disc so as to be symmetrical with respect to the journal bearings 30, 31 whether the fan is in one position or its reversed position. Fur-

thermore, by the use of such asymmetrical disc the individual blades may be reversed in their positions on the disc 25 when the fan is to be changed from a suction fan to a blower or vice versa. The holes 60 in the hub end 18 of the blade section 16 enable the bolts 24 to secure the sections detachably to either side of the disc 25. The leading edges 21 should all be arranged so as to move in the desired direction of rotation. For instance, when the blades 16 are 10 mounted as shown in Fig. 3 the direction of rotation is anti-clockwise as viewed in the direction of the arrow 58.

Although the fan unit comprising the hub 26, the disc 25 and the blades 16, may be reversed 15 by detaching the inner framework from the casing 10 and sliding the hub 26 off the shaft 27 and then after reversal replacing the hub on the key 59, I prefer to reverse the blades individually because of the ease with which this may be done 20 after an installation has been made. By referring to Fig. 3 it can readily be seen that when the blades are reversed by bolting to the opposite side of the disc 25 the tips of the blades relative to the lip 62 may be adjusted by loosening the set 25 screws 61, sliding the hub 26 to proper position and re-tightening the set screws.

That is to say, after being individually reversed the blades 16 may be brought into the desired plane of rotation relative to the casing 10 by adjusting the hub 26 on the shaft 27. Sufficient clearances between the ends of the hub 26 and the bearings 30, 31 are provided to permit limited longitudinal movement of the hub along the key 59. The fan structure may be secured in adjusted position by means of the key set screws 61, 61.

The two frames comprising the bars 32, 33 and pipe pedestals 36, 37 are each detachably secured to the casing 10. The lower ends of the pipes may be removably secured to the sockets 38 and 39 by means of set screws 38' and 39', and the sockets themselves may be detachably secured to the casing 10 by means of the bolts 36', 37'.

Covering the bearings 30 and 31 are hollow shells or deflectors 43, 44 each of about the diameter of the disc 25 and shaped so as to direct the flow of air along curved paths from the center of the deflector facing the current of air to the annular passageway in the plane of rotation of the fan. The shape of each deflector is such that when the flow of air is against the same it reduces the tendency of the air current to contract when in the plane of rotation of the fan. Whether the fan acts as a blower to force air into the coal mine or as a suction fan to take air out of the coal mine the flow of air through the casing 10 will be with maximum efficiency since the full cross-sectional area of the annular passageway is effective.

When the flow of the air is into the coal mine 60 the inner deflector 43 prevents back flow of the air and when the flow is out of the coal mine the outer deflector 44 acts to prevent back currents of air. It will thus be seen that the shells 43 and 44 each serves a double purpose in that each prevents back flow of air and moreover each acts when the flow of air is against it to efficiently direct the flow of air into the plane of operation of the rotary fan.

As shown in Fig. 7, which is a sectional plan 70 view of the lower half of the deflector 44, the latter is provided with a slot 43' to fit over the vertical pipe 36, and also with slots 45 and 46 for fitting over the bar cross-beam 32.

The lower portion of the shell 44 is provided 75

with lateral extensions 47 and 48 which are adapted to fit over the cross-beam 32' as shown in Fig. 2 which is a section taken on the line 2—2 looking in the direction of the arrows. By means of screws 49 the lateral extensions 47, 48 may be detachably secured to the cross-beam 32. In a similar manner the deflector 43 may be detachably secured to the cross-beam 33.

It should be particularly noted that the upper, lower and forward sides of the extensions 47, 48 are curved as shown at 50, 50', 51 and that the exposed edge of the flat bar 32 is flush with the adjacent surfaces of the extension 48 as shown at 52 in Fig. 2. The bar 32 is flat and relatively thin and the extension is arranged as shown in Figs. 1 and 2 to reduce interference with the flow of air into the fan casing. The ends of the screws 49 are arranged to be flush with the surfaces 50, 50'.

In co-operation with the curved surfaces of the deflector 43, 44 I have provided surfaces 54 and 55 at the inlet and outlet respectively, each surface having the shape of a frustum of a cone. The surfaces at 54, 55 are preferably so shaped as to have such a path as to be in co-operation with the path afforded by the shells 43, 44, to form approximately a Venturi duct.

In this manner the annular inlet port converges to the plane of operation of the fan blades and the outlet port diverges from such plane. By providing such annular ports with the walls thus shaped the stream of air flows through the annular passageway with uniform density and the friction along the inlet and outlet surfaces is reduced to a minimum. In other words, the flow of air is so effectively directed and controlled that while passing through the casing it is acted upon with maximum efficiency by the fan blade sections.

However, since the tips of the fan blade sections must be spaced from the fan casing an appreciable leakage takes place from the inlet surface to the outlet surface 54 as viewed in Fig. 3. There is also a tendency for the centrifugal forces exerted by the fan blade sections to produce local eddy currents at the fan blade tips thereby causing back flow of the air instead of useful forward flow toward the outlet.

In order to reduce to a minimum the losses at the tips of the aerofoil sections I have provided an annular inwardly projecting lip or baffle plate 62 between the inlet and outlet surfaces 54, 55 as shown in Figs. 3 and 4. I have also squared the tips of the blades at 63 as have edges at right angles to axial line 20. I have found by experiment that the annular lip 62 must be located at the rear of the tips of the blades in order to obtain maximum efficiency of operation of the fan as a unit. For instance, when the fan is rotating in such a direction as to force the air in the direction of the arrow 58 of Fig. 3 the annular lip will be located relative to the blade tips as shown in full lines in this view. It is therefore important to reverse the fan blade unit to the dotted line position shown in Fig. 3 when the flow of the air is to be in the direction of the dotted line arrow 58'.

It has also been found by experiment that to obtain maximum efficiency the overlapping of the approximately square tips of the blades relative to the annular lip 62 should be varied when the size of the fan is varied. For instance, the overlapping measured radially in fans up to six feet in diameter should be $\frac{1}{2}$ "; for fans seven or eight feet in diameter such overlapping should

be $\frac{5}{8}$ "; and for fans nine or ten feet in diameter the overlapping should be $\frac{3}{4}$ ".

It can readily be seen by referring to the parts shown in full lines in Fig. 3 that when the air flow is in the direction of the arrow 58 the annular plate 62 acts as a deflector of the air flowing along the surface of the inlet 54 to counteract the tendency of the blade sections to produce a centrifugal action on the air and at the same time such annular plate acts as an abutment or baffle to prevent back flow thereby counteracting the tendency of the blade tips to produce eddy currents. The squaring of the blade tips as shown at 63 in Fig. 5 increases the area of gripping action on the air between the blades and front surface of the lip 62. The latter is therefore effective in co-operation with the blade sections with its pitch angles as shown in Fig. 6 and as predetermined according to the formula above set forth, to reduce to a minimum the losses at the blade tips by maintaining uniform volume and velocity over the entire area of the passageway through the fan casing.

By referring to Figs. 5 and 6A to 6H, inclusive, it will be understood that the efficiency of operation of the ventilator depends upon the shape of the aerofoil sections and the positions of the various surfaces at the cross-section increments illustrated in Figs. 6A to 6H, inclusive. Assuming the blade to be rotating in the direction of the arrow 23 in Fig. 5, the impelling surface 17 has the maximum pitch angle ($33^{\circ} 12'$) where the circle of rotation is the smallest and the minimum pitch angle (12°) at the tip of the blade where the circle of rotation is the greatest.

The air impinging or propelling surface 17 is warped or spiraled as shown in Figs. 6A to 6H, inclusive, in accordance with the increasing lengths of the circles through which the various radial portions of the blade travels. Furthermore, the outer portion of each blade is tapered toward the tip in the plane of rotation of the fan as viewed in Fig. 3 and is also tapered toward the tip relative to the direction of movement of the air through the ventilator as indicated by the arrow 58.

The leading edge portions of each blade is of decreasing thickness radially outward as shown in Figs. 6A to 6H, inclusive, to provide suction surfaces 19 of gradually decreasing pitch angles radially outward. It will also be seen that the various sections illustrated in Figs. 6A to 6H, inclusive, occupy gradually decreasing spaces between parallel planes at right angles to the section line 20.

The circles of rotation increase in length radially outward and therefore the speed of travel of the various sections illustrated in Figs. 6A to 6H, inclusive, increases gradually radially outward. The forces exerted by the impelling surface 17 and the suction surface 19 are consequently distributed radially outward to produce a uniform pressure over the entire area of the opening through the ventilator to effect a uniform flow of air volume over such area in the direction of the arrow 58 parallel to the axis of rotation of the fan unit.

In other words the air impelling action and the air suction action each varies in accordance with the lengths of circles of rotation with the result that in cooperation with the inlet and outlet surfaces 54 and 55 and the central circular supporting structure, the blower action on the air will be uniformly distributed as to pressure and volume over the entire annular area of the opening

through the ventilator, thereby greatly increasing the efficiency of the ventilator.

By reason of the tapering of the elongated aerofoil blades radially outward and the distribution of the impelling and suction surfaces 17 and 18, and particularly due to the selection of a pitch-diameter ratio

$$\left(\frac{P}{D}\right)$$

of approximately 64 per cent, there is inherent in the rotary fan unit as determined by actual experiment a self-limitation feature in that when an electric motor is provided for normal operation under given conditions the fan head or resistance in the duct 15 may be increased or decreased within wide limits without overloading the motor.

For instance, if the ventilator is used to introduce air into a coal mine and the air passageways between the intake opening of the mine and the outlet thereof are abnormally restricted by a heavy fall or subsidence of the roof of a mine entry, or the air passageways in the mine are otherwise unduly restricted, the fan head may be increased to such an extent that there will be a tendency to overload the motor in its effort to operate a ventilating fan against the increase in pressure or resistance. However, by reason of the structure shown in the accompanying drawings there will be sufficient slip of the fan blades relative to the air acted on by such blades as to prevent overloading of the motor.

If a door in a break-through in a coal mine near the intake opening should be left open accidentally, the air in the ventilating passageways in the mine would be short-circuited and the tendency of the motor would be to be overloaded by reason of the increased volume of air sent into the mine by the ventilator. But here again the self-limiting feature of the fan unit shown will also prevent overloading of the motor.

Heretofore an electric motor of sufficient horsepower to take care of such abnormal loads was required to operate mine ventilating fans but by reason of the self-limiting feature of my improved fan structure a smaller motor may be used than is required otherwise. That is to say, my improved fan structure permits the use of a motor of substantially constant horsepower for a wide range of conditions which vary automatically and are beyond the control of the operator of the ventilator.

This application is a continuation in part of my co-pending application Ser. No. 569,460, filed October 17, 1931, for an Improvement in ventilators.

Obviously those skilled in the art may make various changes in the details and arrangement of parts without departing from the spirit and scope of the invention as defined by the claims hereto appended, and I wish therefore not to be restricted to the precise construction herein disclosed.

Having thus described and shown an embodiment of my invention, what I desire to secure by Letters Patent of the United States is:

1. In a ventilator, the combination with a casing having intake and outlet converging and diverging peripheral surfaces, of a rotary fan unit within said casing comprising a radial aerofoil blade, and an inwardly projecting annular lip between said intake and outlet surfaces adjacent the blade tip of said fan unit and in radial overlapping relation with the tip of said blade.

2. In a ventilator, the combination with a casing having intake and outlet converging and diverging peripheral surfaces, of a rotary fan unit within said casing comprising an aerofoil blade, an inwardly projecting annular lip between said surfaces, and means for supporting said fan unit with the tip of said blade adjacent said lip and radially overlapping said lip on that side thereof adjacent to said intake surface.

3. In a ventilator, the combination with a casing having inner peripheral inlet and outlet surfaces, of an inwardly projecting annular lip between said surfaces, a fan unit within said casing comprising an aerofoil blade having a tip edge extending approximately along a straight line at a right angle to the radial axial line of said blade, and means for mounting said fan unit for rotation concentrically with the annular lip with said straight edged tip in radial overlapping relation to said lip and closely adjacent thereto on the inlet surface side thereof.

4. In a ventilator, the combination with a casing having converging and diverging inlet and outlet inner peripheral surfaces, of an annular lip projecting inwardly from said casing in a plane extending through the merger between said surfaces, a rotary fan unit comprising a plurality of aerofoil sections each having an impelling surface of gradually decreasing pitch angles radially outward to secure uniform distribution of pressure and volume of air through said casing, and means for mounting said fan unit with the tips on either side of said lip for rotation in such direction that the tips shall be in the angular space between the inlet surface and said lip.

5. In a ventilator, the combination with a casing having converging and diverging inlet and outlet inner peripheral surfaces, of an annular lip projecting inwardly from said casing in a plane extending through the merger between said surfaces, a rotary fan unit comprising a plurality of aerofoil sections with squared tips, means for mounting said fan unit within said casing with said tips on either side of said lip in radial overlapping relation therewith, said tips being displaced therefrom an amount determined by the diameter of the circle inscribed by the tips during rotation of said fan unit.

6. In a ventilator, the combination with a casing having converging and diverging inlet and outlet inner peripheral surfaces, of an annular lip projecting inwardly from said casing in a plane extending through the merger between said surfaces, a rotary fan unit within said casing comprising a plurality of aerofoil propeller blades, a rotatably mounted support for the inner ends of said blades, each blade having an impelling and a non-impelling surface on the leading side, said impelling surface being of decreasing pitch angles radially outward and terminating when the pitch angle increases to approximately 33 degrees; deflecting means adjacent the support and non-impelling blade surface to direct fluid flow which, in cooperation with said casing peripheral surfaces, effectively directs the fluid flow to the area swept by the impelling surface of the blades during rotation thereof, and means for mounting said fan unit with the tips on either side of said lip for rotation in such direction that the tips shall be in the angular space between the inlet surface and said lip.

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