April 25, 1961 W. A. OMOHUNDRO 2,981,464

MULTIPLE PROPELLER FAN

Filed July 22, 1958

FIG. 1.

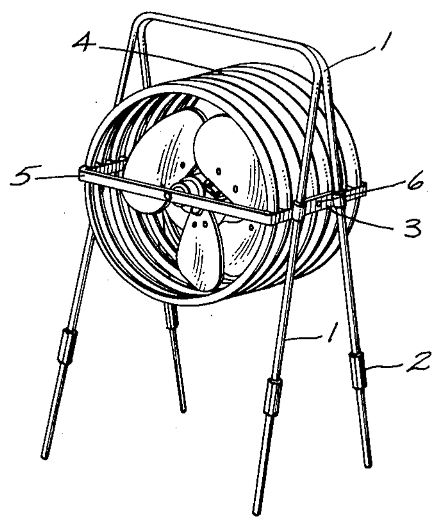


FIG. 2.

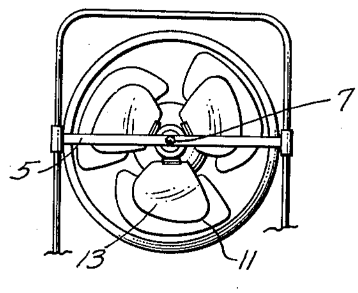


FIG. 3.

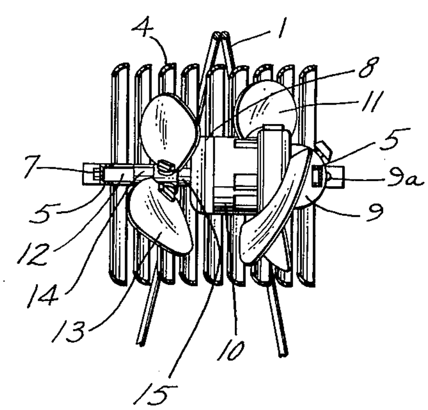


FIG. 4.

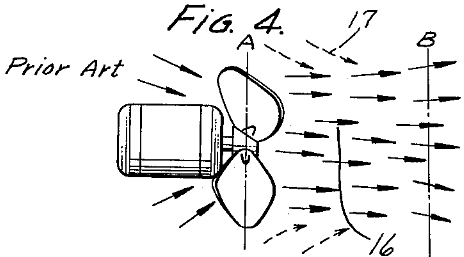


FIG. 5.

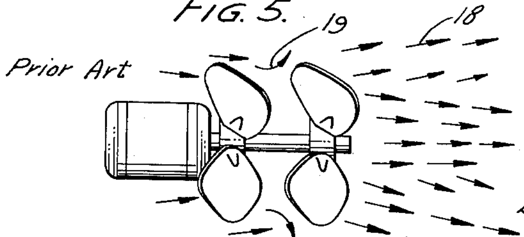


FIG. 6.

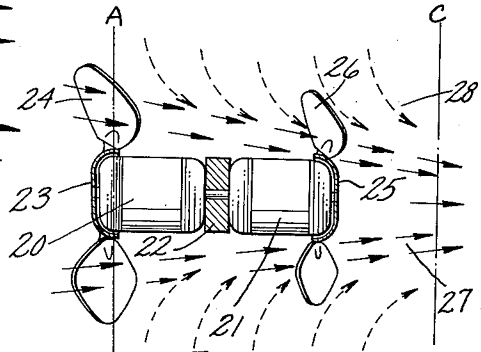
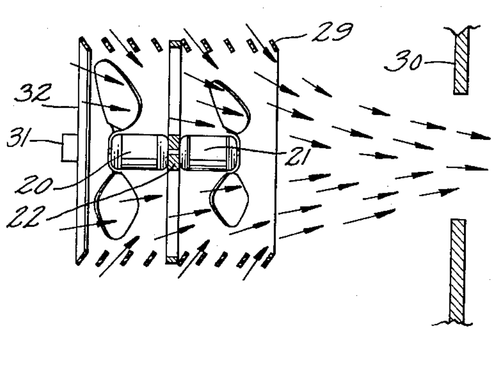


FIG. 7.



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United States Patent Office

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MULTIPLE PROPELLER FAN

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6 Claims. (Cl. 230—259)

My invention relates to fans and more particularly to multiple propeller fans.

Heretofore, multiple propeller fans have been used primarily in applications wherein a fluid is delivered against a moderately high resistance to the fluid flow; however, they have had only limited use in "free air" arrangements in which the fan is not enclosed in ducting and air is drawn from, and discharged into, open spaces. This has been due to the relatively poor efficiencies presently achieved by multiple propeller fans in moving large air masses at low pressures. The limited use and poor efficiencies of the present multiple propeller fans have been determined by my tests to be a direct result of the aerodynamically inefficient fluid flow pattern developed in these fans.

I have found that a superior fluid flow pattern and greater efficiency can be achieved by utilizing propellers of different diameters wherein the smaller diameter propeller is located downstream from the larger diameter propeller and cooperates with the flow pattern formed by the larger diameter propeller to give a more efficient combined flow pattern. The combined flow pattern improves the over-all operating characteristics of the multiple propeller fan to such an extent that its feasibility for extensive use is greatly enhanced.

Accordingly, it is an object of my invention to provide an improved multiple propeller fan.

Another object of my invention is to provide an improved multiple propeller fan which is particularly suited for free air operation.

A further object of my invention is to provide a multiple propeller fan having a high air capacity and a compact arrangement.

Further objects of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

Briefly stated, in accordance with one embodiment of my invention, I provide a two propeller fan having an upstream propeller which is larger in diameter than the downstream propeller of the fan. The propellers are rotated about a common axis of rotation and are axially spaced apart. The larger upstream propeller imparts an axial movement to the fluid stream which, in turn, results in a fluid flow pattern that contracts radially as it progresses through the fan. The smaller downstream propeller is spaced apart from the upstream propeller and has a diameter such that its blades maintain the radially contracting pattern. This arrangement creates a pressure differential between the surrounding static body of fluid and the fluid stream such that additional fluid is caused to flow into and along with the main fluid stream thereby giving a greater total flow. Louvers may be positioned about the fan to assist in efficiently directing the surrounding static fluid into the main fluid stream, and the propellers may be made contra-rotating to eliminate swirling and increase the fan efficiency.

It is believed that the invention will be better understood from the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of a fan embodying the invention;

Fig. 2 is an end elevation view of the fan shown in Fig. 1;

Fig. 3 is a side elevation view, partly in section, of the fan shown in Fig. 1;

Fig. 4 is a diagrammatic view illustrating the approximate path of air flow through a conventional single propeller fan;

Fig. 5 is a diagrammatic view illustrating the approximate path of air flow through a conventional two propeller fan;

Fig. 6 is a diagrammatic view illustrating the approximate path of air flow through a fan embodying this invention wherein two separate motors are used to drive the fan blades; and

Fig. 7 is a diagrammatic view illustrating the approximate path of air flow through a louvered fan of the type shown in Fig. 6.

Referring to Fig. 1, there is shown one embodiment of my invention as applied to a free air fan for use in the cooling and ventilating of a room. In this arrangement, the fan includes a pair of U-shaped supporting frames **1** which are mounted together in the form of an inverted V. A plurality of turnbuckles **2** are positioned on the legs of the supporting frames for adjusting the height above the floor at which the fan is to operate. In order to provide means for holding the supporting frames together and to allow the fan to be held in place by the supporting frames, supporting plates, one of which is shown at **3**, are provided. A shroud ring assembly, shown generally at **4**, is positioned circumferentially about and spaced from the rotating components of the fan. The shroud ring **4** is welded or otherwise fastened to a strap **5** which encircles the shroud ring and provides a convenient arrangement for mounting the fan to the supporting plates by means of the bolts **6**.

As may be more clearly seen in Fig. 2, strap **5** is arranged to provide a first end support **7** for the fan components located within the shroud ring. The end support is centrally positioned with respect to the shroud ring and intersects the rotational axis of the fan. A bearing support may be bolted or otherwise mounted to the strap in any manner well-known to the art.

The arrangement of the fan components located within the shroud ring may be better understood by referring now to Fig. 3. A motor, shown generally at **8**, is provided having a stationary end bell **9**. The end bell is slotted to allow the strap **5** to form an interlocking fit with it and the strap and end bell are securely fastened together by means of a bolt **9*a***. This arrangement furnishes a second end support for the fan components located within the shroud ring. These components comprise a rotating motor casing **10** upon which is mounted an upstream fan **11**. The upstream fan is caused to rotate in one direction while the motor is energized. A motor shaft **12**, driven by the armature of the motor **8** is arranged, in this embodiment, to rotate in a direction opposite to that of the upstream fan **11**.

The particular structure used to achieve contra-rotating fan blades will not be discussed in detail since the prior art is replete with patents showing details of contra-rotating fan propeller structures. The patent to Persons 1,861,608 is indicative of prior art contra-rotating fans wherein one propeller is mounted on a rotating structure and the second propeller is driven in an opposite direction by means of a contra-rotating armature.

An oppositely pitched downstream propeller **13** is mounted for rotation with shaft **12**. The downstream propeller **13** is positioned axially with respect to upstream propeller **11** by means of shaft collars **14** and **15** or by any other well-known means. The downstream propeller **13** is made smaller in diameter than upstream propeller **11**, as may more clearly be seen in Fig. 2, in order to achieve the optimum results of my invention.

It will be helpful at this point, in order to obtain a better understanding of my invention, to draw an analogy between the flow of a fluid through and downstream of a propeller and the flow of fluid through an aperture or an orifice. For purposes of definition, the term "vena contracta" will be used to indicate the converging portion of a fluid stream discharging on the downstream side of a propeller. The vena contracta formed downstream of a propeller has a contracting or converging diameter portion which is similar in character to the characteristic contracting portion of a jet of fluid discharging from an aperture or an orifice. The vena contracta exists between the propeller blade and the point of minimum diameter. At this point the fluid stream takes on a divergent or expanding diameter form.

Referring to Fig. 4, which shows the fluid flow pattern resulting during rotation of a conventional fan, lines A and B represent the limits between which the vena contracta exists. The solid arrows **16** in this area represents the fluid stream flow pattern developed by the propeller. When the propeller is rotated, movement is imparted to the surrounding static fluid mass. The resultant high velocity fluid stream has a lower pressure, due to its high velocity, than exists in the static fluid mass. The fluid stream encounters resistance to flow by the fluid molecules in its path and the main fluid stream converges in diameter as the pressure within the fluid stream begins to drop. When line B is reached, the converging fluid stream has experienced a sufficient pressure drop to no longer maintain its converging character. Line B may be additionally analogized to represent the throat area or minimum diameter portion of a round cross-section streamlined nozzle. At this point, the fluid stream takes on a diverging character and penetration by the fluid stream is considerably deterred. Within the space denoted by lines A and B on Fig. 4, and while the fluid stream is in its vena contracta condition, additional surrounding fluid is drawn into and along with the main fluid stream **16**, as shown by the dotted arrows **17**. This additional flow is caused by the lowering of pressure in the vena contracta due to the high velocity convergent character of the main stream **16**. Since there is a low pressure area within the vena contracta, additional fluid flow is achieved by the pressure differential existing between the surrounding fluid mass located at a distance from the main fluid stream and that fluid pressure existing in the vena contracta.

Referring now to Fig. 5 it may be seen that the addition of a downstream propeller that is of equal size with the upstream propeller results in a downstream flow pattern that is no longer convergent as is indicated at **18**. This results from the fact that the vena contracta leaving the upstream propeller is disturbed by, and caused to expand rapidly within, the downstream propeller due to its diameter being substantially larger than the vena contracta at that point. As a result, considerable penetrating ability and additional influx from the surrounding fluid mass is lost on the downstream side of the downstream propeller. In addition, the fluid flow in the area between the two propellers is such that the main stream is divergent in character in this area as is shown generally by the radially outwardly flowing arrows at **19**. This condition is greatly accentuated if both propellers rotate in the same direction. The accentuation is the result of an increase in the rotational component of velocity which in turn causes the fluid stream to expand radially.

Referring now to Fig. 6, a modification of my invention is shown wherein separate motors are used to drive the upstream and downstream propellers. Upstream motor **20** and downstream motor **21** are bolted or otherwise mounted to a support bracket **22** to locate the propellers with respect to each other. An upstream hub **23** upon which upstream propeller **24** is mounted, is driven by the armature of upstream motor **20**. A downstream hub **25** upon which downstream propeller **26** is mounted, is driven by the armature of downstream motor **21**.

I have found that by using a downstream propeller of substantially the diameter of the vena contracta formed by the upstream propeller, the vena contracta may be smoothly prolonged to exist for a considerable distance downstream of the downstream propeller. By elongating the vena contracta, additional surrounding fluid is drawn into and along with the main fluid stream over a greater distance, thereby resulting in an appreciable increase in flow over a conventional two propeller fan arrangement. Minor deviations in the diameter of the downstream propeller with respect to the vena contracta may be made without seriously affecting the total flow of the fan. However, if the downstream propeller is made either too small or too large for its axial position within the vena contracta, the effect of prolonging the vena contracta may be lost.

The advantages of my invention may be obtained by utilizing a downstream propeller having a diameter within a given range which will effectively prolong the vena contracta. I have found that the maximum diameter of this range occurs when the downstream propeller is no greater than the average of the diameters of the upstream propeller and of the vena contracta at the axial position of the downstream propeller. I have further determined that the minimum diameter of this range should be no less than half the diameter of the upstream propeller.

For the purpose of defining the axial spacing relationship between the two propellers, I have found that greatly improved results over a conventional two propeller fan may be obtained when the downstream propeller is positioned axially from the upstream propeller within the range of one-third to two times the diameter of the upstream propeller.

With respect to the relationship of rotational speeds between the two propellers, I have found that when using contra-rotating propellers the speed relationship is not critical and the two propellers may run at substantially the same rotational speed. The optimum speed relationship for a contra-rotating two propeller fan occurs when the blade tip linear velocities of the two propellers are equal. This may be accomplished by driving the smaller downstream propeller at a greater rotational speed than the upstream propeller in an amount dependent on the relationship of the diameters of the two propellers.

On the other hand, however, when using propellers which rotate in the same direction the speed relationship becomes more important. The importance increases since considerable swirling of the fluid stream is developed which may result in a decreased ability to draw the surrounding fluid mass into the vena contracta. It therefore becomes necessary to increase the speed of the downstream propeller to restore the higher air flow. Optimum results are achieved when the downstream propeller rotational speed has been increased to the point where the propeller blade tips of the two propellers have an equal linear velocity.

As shown in Fig. 6, the vena contracta has been prolonged from point A at the center of the upstream propeller to a point C located downstream from the downstream propeller. The exact positioning of point C is dependent upon the type motors used, configuration of the blades, speed of the propellers, and direction of rotation of the propellers. However, it is apparent that surrounding fluid will be drawn into and along with the main fluid stream **27** over a considerably longer distance as denoted by the dotted arrows **28**.

The final diagrammatic view, Fig. 7, incorporates the use of louver vanes 29 to assist in properly directing surrounding fluid into the path of the vena contracta formed by the two propeller fan. I have found that the use of louver vanes whose discharge edges are positioned at an angle of 60 degrees to the axis of rotation of the fan provides the most efficient arrangement; however, the louver vane discharge edges may be positioned at any angle between 45 degrees and 90 degrees to the axis of rotation and still achieve results superior to the use of the two propeller fan without louvers.

When used to ventilate a room, the fan might be placed in front of a window 30 and arranged so that it is at the same height as, and directing its flow out of, the window. By positioning the fan upstream from the window so that the vena contracta minimum diameter point occurs at the window, maximum air flow from the surrounding area and out of the window is obtained.

In order to provide means for adjusting the speeds of the two motors to their optimum relationship, a dual switch 31 is shown mounted on radial struts 32 which are positioned at the upstream end of the fan. Through judicious selection of speed positions on switch 31 in accordance with the criteria previously pointed out, the optimum speed settings for motors 21 and 22 may be achieved in order to fully utilize the beneficial results of my invention.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspect, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. In a multiple propeller fan having means for rotating the propellers about a common axis, a first propeller for forming a convergent fluid stream, a second propeller axially spaced downstream from said first propeller, said propellers having substantially unrestricted contact with a surrounding fluid medium, said second propeller being smaller in diameter than said first propeller, the diameter of said second propeller being substantially equal to the diameter of said convergent fluid stream at the axial position of said second propeller, said second propeller being rotatable at a greater rotational speed than said first propeller, said rotational speeds being such that the propeller blade tip linear speeds of said first and second propellers are substantially equal.

2. In a multiple propeller fan having means for rotating the propellers about a common axis, a first propeller for forming a convergent fluid stream, a second propeller axially spaced downstream from said first propeller, said second propeller being smaller in diameter than said first propeller, the diameter of said second propeller being substantially equal to the diameter of said convergent fluid stream at the axial position of said second propeller, louver vanes positioned circumferentially about and spaced from said propellers, said vanes being axially spaced from each other and forming a shroud which extends axially at least from said first propeller to said second propeller, said vanes having discharge edges that form an angle with the axis of rotation of at least 45 degrees.

3. A fan as described in claim 2, wherein said first and second propellers have oppositely pitched blades and are driven in opposite directions.

4. In a multiple propeller fan having means for rotating the propellers about a common axis, a first propeller for forming a convergent fluid stream, a second propeller axially spaced downstream from said first propeller, said second propeller being smaller in diameter than said first propeller, the diameter of said second propeller being substantially equal to the diameter of said convergent fluid stream at the axial position of said second propeller, said second propeller being rotatable at a greater rotational speed than said first propeller, said rotational speeds being such that the propeller blade tip linear speeds of said first and second propellers are substantially equal, louver vanes positioned circumferentially about and spaced from said propellers, said vanes being axially spaced from each other and forming a shroud which extends axially at least from said first propeller to said second propeller, said vanes having discharge edges that form an angle with the axis of rotation.

5. In a free air fan of the multiple propeller type, first and second propellers of different diameters, said propellers having substantially unrestricted contact with a surrounding air mass, said first propeller being upstream from said second propeller, said first propeller being larger in diameter than said second propeller, said second propeller being rotatable at a greater rotational speed than said first propeller, said rotational speeds being so related that the propeller blade tip linear speeds of said propellers are substantially equal, said second propeller being mounted for opposite rotation about the same axis of rotation as said first propeller and axially spaced apart from said first propeller, the spacing between said propellers being at least one-third and not more than twice the diameter of said first propeller, and shroud means including a plurality of louver vanes positioned circumferentially about and spaced from said propellers, said vanes being axially spaced from each other, said shroud extending axially at least from said first propeller to said second propeller, said vanes having discharge edges that form an angle of substantially 60 degrees with the axis of rotation.

6. In a multiple propeller fan having means for rotating the propellers about a common axis, a first propeller for moving a convergent fluid stream, a second propeller axially spaced down stream from said first propeller, said propellers having substantially unrestricted contact with the surrounding fluid medium, said second propeller being smaller in diameter than said first propeller, the diameter of said second propeller being substantially equal to the diameter of said convergent fluid stream at the axial position of said second propeller, said second propeller being oppositely pitched with respect to said first propeller, and said propellers being driven in opposite directions.

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