May 19, 1942. J. E. McDONALD 2,283,609

FAN

Filed Nov. 8, 1939 2 Sheets-Sheet 1

Fig. 1

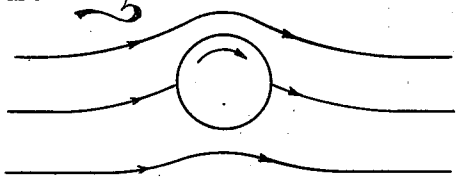


Fig. 2

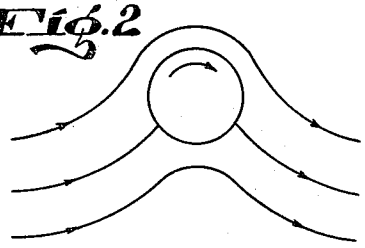


Fig. 3

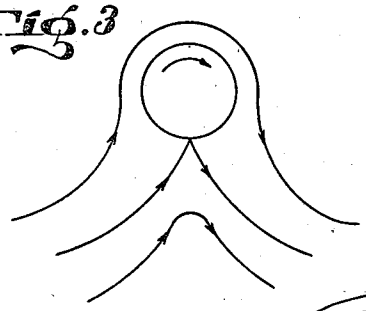


Fig. 4

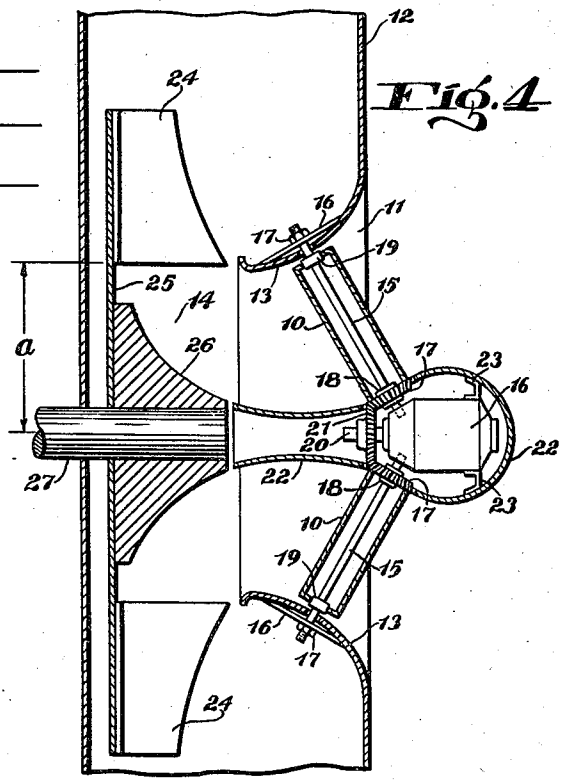
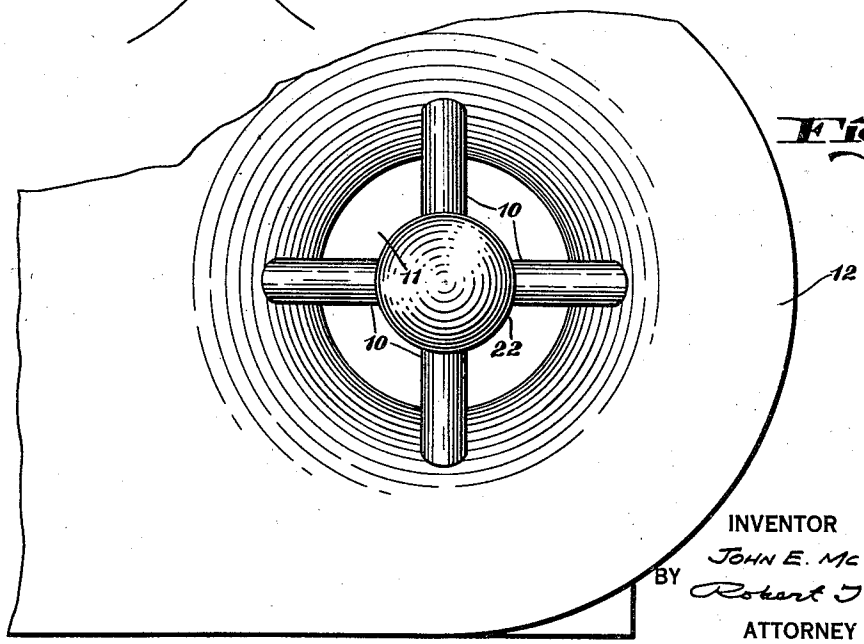


Fig. 5



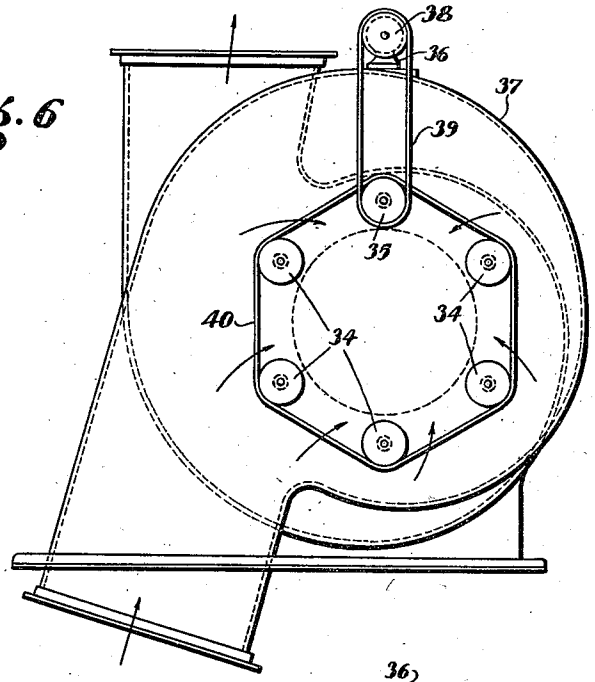
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FAN

Filed Nov. 8, 1939 2 Sheets-Sheet 2

Fig. 6



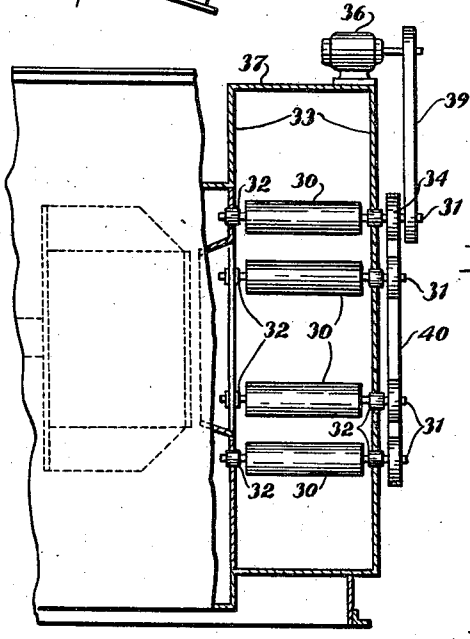


Fig. 7

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FAN

John E. McDonald, Boston, Mass., assignor to B. F. Sturtevant Company, Hyde Park, Boston, Mass.

Application November 8, 1939, Serial No. 303,412

6 Claims. (Cl. 230—114)

This invention relates to methods of and apparatus for controlling the volume of air moved by fans.

An object of the invention is to utilize the so-called "Magnus effect" for varying and controlling the volume of air moved by fans.

Another and more definite object of the invention is to utilize so-called "Flettner" rotors in the inlet of a fan for varying the spin velocity of the air entering the fan.

As discussed in the U. S. Patent No. 1,846,863 issued Feb. 23, 1932, on an application of H. F. Hagen, it is desirable to operate a fan at constant speed and to vary the volume of the air moved by the fan by varying the spin velocity of the air entering the fan, in the direction of rotation of the fan blades.

This invention utilizes rotors in a fan inlet, so positioned and so rotated about their axes, as to control the volume of air moved by the fan by varying the spin velocity of the air entering the fan, in the direction of rotation of the fan blades.

In one embodiment of the invention, a plurality of rotors are mounted in the inlet of a fan with their axes converging towards the axis of the fan.

In another embodiment of the invention, a plurality of rotors are mounted with their axes substantially parallel, around the inlet of a fan.

In all embodiments of the invention, the volume of air moved by the fan is controlled by varying the speed of rotation of the rotors about their axes.

The invention will now be described with reference to the drawings, of which:

Fig. 1 is a diagrammatic view illustrating the action of an unconfined rotor revolving at low speed, upon air moving past it;

Fig. 2 is a diagrammatic view similar to Fig. 1 but illustrating the rotor revolving at a higher speed.

Fig. 3 is a diagrammatic view similar to Fig. 2 but illustrating the rotor revolving at a higher speed;

Fig. 4 is a partial transverse section through a centrifugal fan embodying this invention;

Fig. 5 is a side view looking into the eye of the fan of Fig. 4;

Fig. 6 is a side view of another embodiment of this invention applied to a centrifugal fan having an involute casing, and

Fig. 7 is a partial transverse section through the inlet box of the fan of Fig. 6.

In any fan, a simple measure of the energy added to each unit volume of air flowing through it, is the expression

$\Delta E = \alpha\rho(Cu_2 r_2 - Cu_1 r_1)$

α=angular speed of the fan wheel

ρ=air density

Cu_1=spin component of velocity of the air at the inlet side of the wheel

Cu_2=spin component at the discharge side of the wheel

r_1=radius at the inlet side of the wheel

r_2=radius at the discharge side of the wheel

As disclosed in said Hagen patent, the useful output of energy of a fan at a constant angular speed, can be reduced by making the term $Cu_1 r_1$ positive. Since in general, r_1 the inlet radius of the fan blading is fixed, such variation in energy output must be accomplished by a variation of the term Cu_1. In said Hagen patent, this variation is obtained through the use of adjustable vanes in the inlet of a fan.

A rotating cylinder in still air will induce about itself a circulatory air motion of such nature that the product of spin or tangential velocity and radius from the cylinder axis, is substantially constant at any point in the air field. This product multiplied by 2π is called the "circulation" about the cylinder. If as illustrated by Figs. 1–3, there is superimposed upon such a circulatory system, a uniform velocity air stream, the air patterns illustrated will result. The stream will be diverted around the cylinder with higher velocities above the cylinder and lower velocities below and with a degree of divergence of the air stream passing the cylinder which varies conformably with increases in the rotative speed of the cylinder.

When revolvable rotors of this type are located in the eye of a fan as illustrated in one embodiment by Figs. 4 and 5 and as illustrated in another embodiment by Figs. 6 and 7, the air passing between the rotors will be given a spin component. The circulation in the air stream behind the rotors will be equal to the sum of the rotor circulations. Since it now seems desirable that circulation should be constant across the section of the air leaving the rotors, it is preferred that the circulation about each rotor should be constant along its length, and that therefore the rotors be substantially cylindrical as illustrated.

The circulation about a rotor may be written

Circulation $= 2\pi RV$ where

R=distance of any point in the air stream from the rotor axis

V=spin or tangential velocity of the air at the reference point.

If the reference point is on the surface of the cylinder, then

Circulation$=2\pi R_0 V_0$ with R_0 the radius of the rotor and V_0 the tip speed of the rotor. But

$V_0=2\pi R_0 S$ where S is the revolving speed of the rotor.

Hence

$$\text{Circulation}=4\pi^2 R_0^2 S$$

If there are Z rotors in all, the total circulation behind the rotors will be

$$\text{Circulation}=Z(4\pi^2 R_0^2 S)$$

Knowing this and calculating the radial velocities through the fan blading from the dimensions of the fan wheel and from the air volume, the performance of the rotors can be calculated. The spin component of the air entering the wheel will be

$$Cu_1=\frac{Z(4\pi^2 R_0^2 S)}{2\pi a}=\frac{Z}{a}(2\pi R_0^2 S)$$

where a is the distance of the base of the blades of the fan wheel from its axis. The energy added to each unit volume of air will be

$$\Delta E=a\rho(Cu_2 r_2-Z(2\pi R_0^2 S)$$

The above formula has been used to calculate the effect of four 3'' radius rotors revolving at 1800 R. P. M. in the eye of a centrifugal fan having a wheel diameter of 34''. Such a wheel may produce an air pressure of 5'' of water with a "$Cu_2 r_2$" of 130 in feet second units. The term $Z(2\pi R_0^2 S)$ will then have a value of approximately 47, as is shown by the substitution of appropriate values.

$Cu_2 r_2-Z(2\pi R_0^2 S)=130-47=83$ and the air pressure with the rotors revolving at 1800 R. P. M. will be by proportion

$$\frac{83}{130}\times 5''=3''$$

The pressure may be increased by slowing down the rotors. At zero R. P. M. the pressure will be 5''. The reduction in pressure may be increased by revolving the rotors at higher speeds.

Due to the nature of air, tests have shown that the performance is not that as mathematically demonstrated in the foregoing. To produce a given reaction, the rotor speeds should be from two to three times higher than the theoretical ones.

To provide more than a 40% reduction in air pressure, the rotor speeds may be so high as to be impractical. But a 40% reduction in pressure results in more than a 50% saving in horsepower and it is now preferred where reductions in pressure of more than 40% are desired, that the further reduction be accomplished as in the past, by dampers.

Since the volume of the air delivered by the fan varies as the square root of the pressure produced, assuming fixed air resistance, changes in the pressure producing capacity of a fan are accompanied by reductions in volume flow.

The cylindrical rotors **10** of Figs. 4 and 5 are arranged in the eye **11** of the centrifugal fan **12**, with their axes extending substantially at right angles to the converging inlet member **13**, and converging towards the axis of the fan wheel indicated generally by **14**.

The rotors **10** are adapted to be rotated about their shafts **15** which are attached at their outer ends to the inlet member **13** by means of the plates **16** and the nuts **17** which are screwed onto the threaded ends of the shafts, against the plates. The inner ends of the shafts **10** are screwed into tapped circular apertures in the casing of the electric motor **16**.

The inner ends of the rotors **10** are attached to the gears **17** which rotate around the bearings **18** on the shafts **15**. The outer ends of the rotors are attached to the bearings **19** which rotate around the shafts **15**.

The armature of the motor **16** drives through its shaft **20**, the gear **21** which meshes with the gears **18** to rotate them and through them the rotors **10** simultaneously and in the same direction.

The stream lining fairing **22** is attached by the clips **23** to the motor **16** and serves to guide the air smoothly around the motor **16** and into the fan wheel **14**. The motor **16**, the rotor assemblies and the fairing are supported by the shafts **15** from the fan housing although external supports may be provided if desired.

The fan wheel **14** consists of the blades **24** which are attached to the back plate **25** which in turn is attached to the stream lining hub **26** which is keyed onto the rotary shaft **27**. The shaft **27** is supported from a conventional bearing pedestal which is not shown. Only two fan blades **24** are illustrated but more would be included in a wheel. For example eight blades could be provided.

The motor **16** is a variable speed electric motor and its speed may be controlled by a conventional controller.

In operation, the fan wheel **14** is driven at a constant speed and the rotors **10** are rotated about their shafts **15** at speeds to give the desired air volumes. If the rotors are not revolved while the fan wheel is rotated, they will have no effect upon the air volume. Their effect when revolving about their axes will vary with their speed of rotation, and this effect may be calculated from the formula and other data given herein.

Figs. 6 and 7 illustrate an application of the invention to a centrifugal fan of the type illustrated by said Hagen patent and which includes an involute casing. In this embodiment, the six rotors **30** have their shafts **31** rotatably supported in the bearings **32** which in turn are supported in the inlet walls **33**. The uppermost rotor **30** has an extended shaft **31** on which is mounted an inner pulley **34** and an outer pulley **35**. The other rotors **30** have shorter shafts **31** on which are mounted only the pulleys **34**.

The variable speed electric motor **36** is mounted on the casing **37** of the fan and has mounted on its shaft, the pulley **38** which is in alignment with the pulley **35**. The belt **39** is fitted around the pulleys **35** and upon rotation of the pulley **38** by the motor **36**, the pulley **35** is rotated.

The inner pulleys **34** are in alignment and are fitted with the belt **40**. Upon rotation of the pulley **35** by the motor **36**, the pulleys **34** are rotated and with them the rotors **30**. The rotors **30** produce variable spin velocities in the air passing between them conformably with their speed formation.

The speed of the electric motor **36** may be adjusted by a conventional controller to adjust the speed of the rotors to provide the desired air volume.

An advantage of the use of rotors for adjusting the air volume is that no throttling effect exists

as in the case of vanes which have previously been used.

While embodiments of the invention have been described for the purpose of illustration, it should be understood that the invention is not limited to the exact apparatus and arrangements of apparatus described, as departures therefrom may be suggested by those skilled in the art without departure from the essence of the invention.

What is claimed is:

1. In a fan having a plurality of rotary, air moving blades and a stationary, air guiding casing forming an axial, air inlet to said blades, a plurality of rotors having shaft supporting means attached to said casing, said rotors being so disposed with respect to the air stream flowing through said inlet that upon rotation thereof, they produce a spin velocity in the air in the direction of rotation of said blades, means independent of the air moved by said fan for rotating said rotors in the direction of the air movement produced in said inlet by the rotation of said blades, and means for adjusting said last mentioned means for varying the speed of rotation of said rotors for varying the volume of air moved by said fan.

2. In a fan having a plurality of rotary, air moving blades and a stationary, air guiding casing forming a converging air inlet to said blades in alignment with the axis thereof, a plurality of rotors having radial shafts, means attached to said casing for supporting said shafts, said rotors being so disposed with respect to the air stream flowing through said inlet that upon rotation thereof, they produce a spin velocity in the air in the direction of rotation of said blades, means independent of the air moved by said fan for rotating said rotors in the direction of the movement of the air by the rotation of said blades, and means for adjusting said last mentioned means for varying the speed of rotation of said rotors for varying the volume of air moved by said fan.

3. In a centrifugal fan having a wheel and a stationary, air guiding casing forming an axial, air inlet to said wheel, a plurality of rotors having spaced shafts, means attached to said casing around said inlet for supporting said shafts, said shafts being substantially parallel to the axis of said wheel, said rotors being so disposed with respect to the air stream flowing through said inlet that upon rotation thereof, they produce a spin velocity in the air in the direction of rotation of said blades, means independent of the air moved by said fan for rotating said rotors in the direction of the movement of the air by the rotation of said blades, and means for adjusting said last mentioned means for varying the speed of rotation of said rotors for varying the volume of air moved by said fan.

4. In a fan having a plurality of air moving blades and an air inlet, a plurality of rotors, means for so supporting said rotors in the path of the air entering said inlet that upon rotation of same about their axes in the direction of the air entering said inlet, a spin velocity in the direction of the rotation of said blades, is produced in the air entering said inlet, said means including shafts and shaft supporting means, said shaft supporting means being stationary, and means independent of the air passing through said inlet for rotating said rotors about their axes in the direction of the air entering said inlet, at variable speeds for varying said spin velocity, for varying the volume of air moved by said fan.

5. In a fan having a plurality of air moving blades and an air inlet, a plurality of rotors, means for so supporting said rotors in the path of the air entering said inlet with their axes converging that upon rotation of same about their axes in the direction of the air entering said inlet, a spin velocity in the direction of the rotation of said blades, is produced in the air entering said inlet, said means including shafts and shaft supporting means, said shaft supporting means being stationary, and means independent of the air passing through said inlet for rotating said rotors about their axes in the direction of the air entering said inlet, at variable speeds for varying said spin velocity, for varying the volume of air moved by said fan.

6. In a fan having a plurality of air moving blades and an axial air inlet, a plurality of rotors, means for supporting said rotors with substantially parallel axes around said inlet, said means including shafts and shaft supporting means, said shaft supporting means being stationary, means for guiding the air entering said inlet in contact with said rotors, and means independent of the air entering said inlet, for rotating said rotors at variable speeds about their axes in the direction of the air entering said inlet, for producing variable spin velocities in the air entering said inlet, for varying the volume of air moved by said fan.

JOHN E. McDONALD.