

Nov. 16, 1965

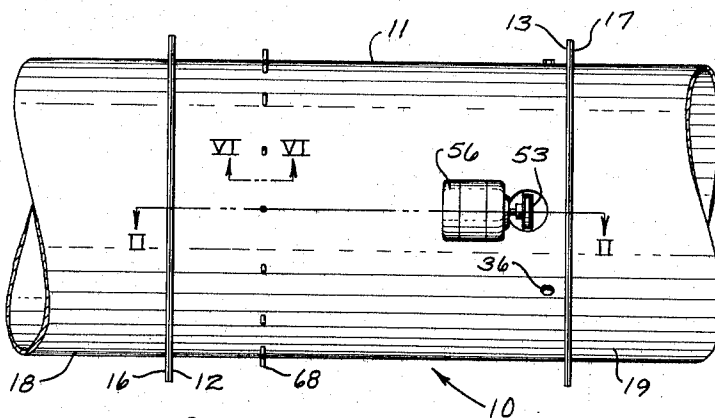
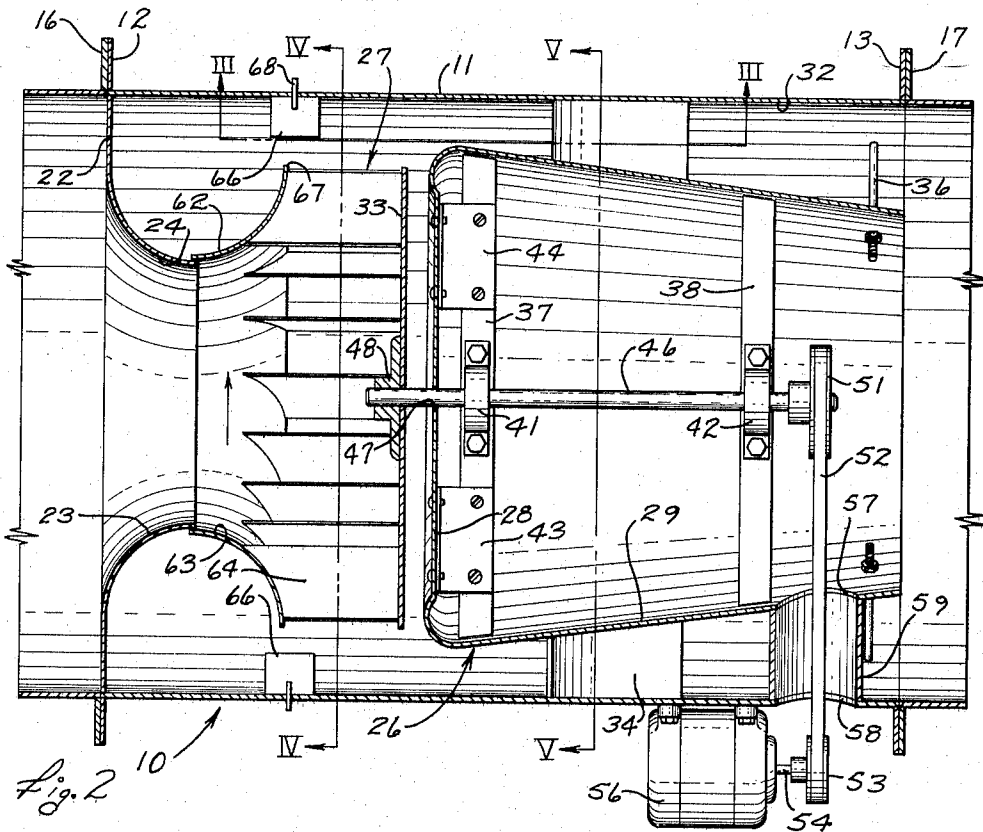
S. H. DOWNS

3,217,976

FAN EQUIPMENT

Filed April 20, 1964

3 Sheets-Sheet 1



INVENTOR.  
SEWELL H. DOWNS  
BY  
*Woodhams, Blanchard & Flynn*  
ATTORNEYS

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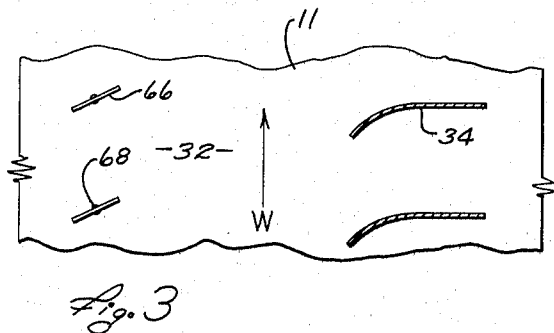
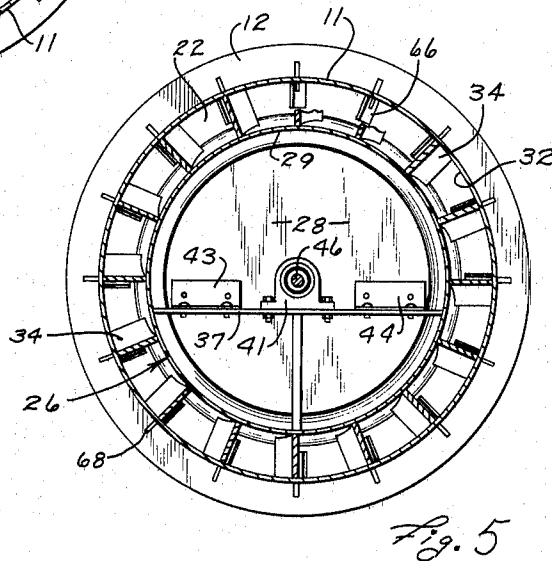
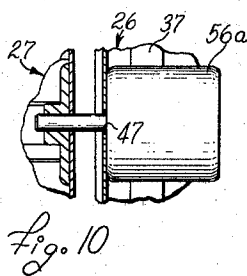
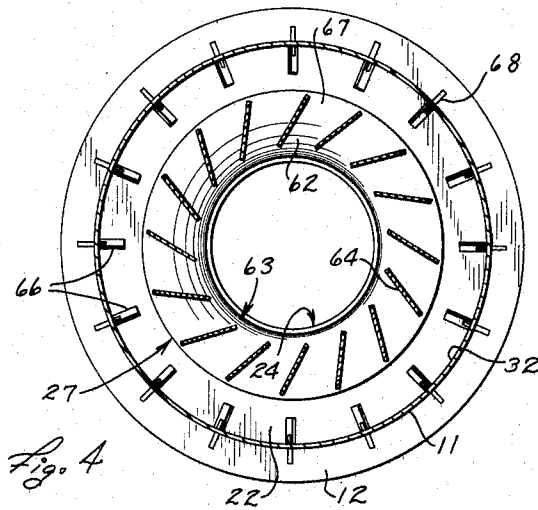
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FAN EQUIPMENT

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BY  
Woodhams Blanchard & Flynn  
ATTORNEYS

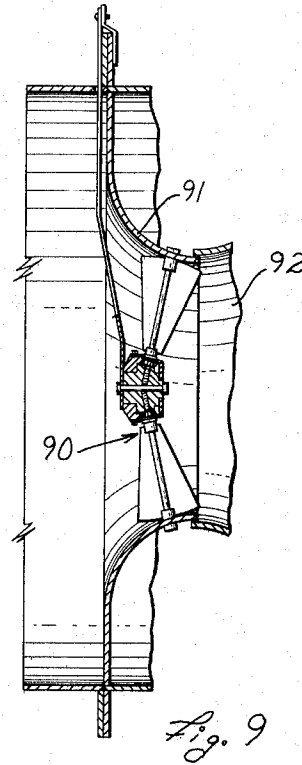
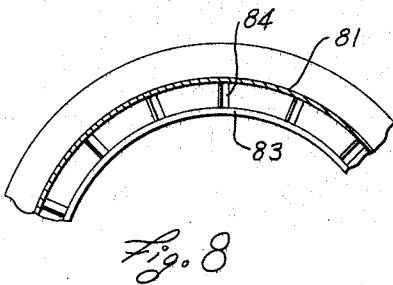
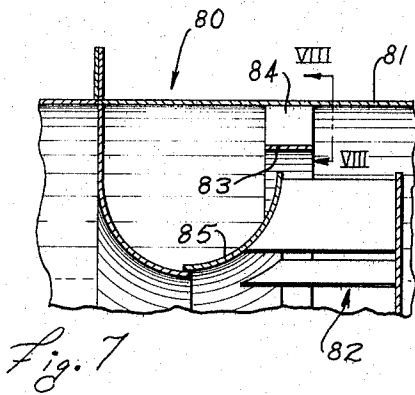
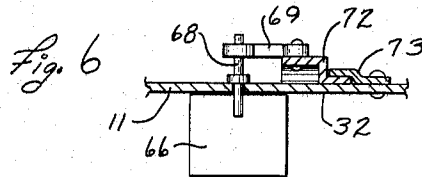
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S. H. DOWNS  
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3 Sheets-Sheet 3



INVENTOR.  
SEWELL H. DOWNS

BY

*Woodhams, Blanchard & Flynn*  
ATTORNEYS

3,217,976

## FAN EQUIPMENT

Sewell H. Downs, Kalamazoo, Mich., assignor to Clarage Fan Company, Kalamazoo, Mich., a corporation of Michigan

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5 Claims. (Cl. 230-127)

This application relates in general to an in-line fan construction utilizing a centrifugal impeller and, more particularly, to an improved type of in-line fan including structure for increasing the output efficiency of the impeller therein.

It is well known that the performance of a centrifugal impeller in the average installation is substantially less than it theoretically could be, if the turbulent conditions, hence losses, which develop in the region of the inlet side of the impeller, could be avoided. Numerous attempts have been made to reduce such turbulence, and an example of one attempt is disclosed in Patent No. 3,011,693, which is assigned to the assignee of this application. However, the apparatus in Patent No. 3,011,693 which is designed to control or improve the flow of the inlet boundary layer, is not applicable in this instance because of the completely different type of discharge arrangement.

While studying the performance of a centrifugal impeller within the housing of an in-line fan construction, it was found that the discharge from the impeller divided, near the inlet side of the impeller into two diverging flow paths which, at one stage, move in substantially opposite axial directions. That is, a relatively large volume of the discharged air is moved by the impeller first radially and then axially toward and through the discharge end of the housing. A smaller, but substantial, amount of the air discharged from the impeller moves in the opposite direction and forms a natural vortex or whirl around the inlet cone and adjacent side of the wheel, the inlet normally in the direction of rotation of the wheel. Thus, in the zone between the two separating flow paths, which has a substantially V-shaped cross section there presently exists a very turbulent condition which as well understood by engineers, produces costly losses of energy and inefficient performance.

During the course of examining carefully the foregoing conditions, it was found that a plurality of spaced flaps disposed at selected positions within the turbulent, annular zone around the inlet side of the centrifugal impeller materially reduced such turbulence and thereby increased the output performance of the impeller, hence of the in-line fan construction. That is, higher pressures and more c.f.m. could be produced with the same installation using the same amount of horsepower input, merely by placing the small flaps or their functional equivalent, in said turbulent annular zone.

In previous experiments conducted in this type of fan construction, it was found that vanes placed in the zone adjacent the peripheral surface of the inlet cone, hence adjacent the inlet side of the impeller, would disturb the natural vortex and would actually reduce the performance of the impeller. Thus, it was not reasonable to expect that a plurality of relatively small flaps or blades located in the annular zone of turbulence, between the two flow paths, would have a contrary, indeed favorable, effect upon the performance of the unit.

Accordingly, a primary object of this invention has been to provide an in-line fan construction including a centrifugal impeller and appropriate apparatus for improving the output performance of such impeller without making material changes in the construction.

A further object of this invention has been the provision of an improved in-line fan construction, as aforesaid, which can be adapted for direct drive operation or

belt driven operation, and which can be adapted for use with inlet vane control, such as the Clarage Vortex Control, or outlet damper control.

A further object of this invention has been the provision of an improved in-line fan construction, as aforesaid, including discharge turbulence control mechanism which can be used with a variety of centrifugal impellers capable of use in an in-line fan construction.

A further object of this invention has been the provision of an in-line fan construction, as aforesaid, which can be made at substantially the same cost as existing in-line fan constructions, and which is capable of better performance with a lower operating cost than existing in-line fan constructions of a similar type for the same or similar purposes.

Other objects and purposes of this invention will become apparent to persons familiar with this type of equipment upon reading the following specification and examining the accompanying drawings, in which:

FIGURE 1 is a side elevational view of an in-line fan construction embodying the invention.

FIGURE 2 is a sectional view taken along the line II—II in FIGURE 1.

FIGURE 3 is a sectional view taken along the line III—III in FIGURE 2.

FIGURE 4 is a sectional view taken along the line IV—IV in FIGURE 2.

FIGURE 5 is a sectional view taken along the line V—V in FIGURE 2.

FIGURE 6 is an enlarged sectional view substantially as taken along the line VI—VI in FIGURE 1 and including a control mechanism which can be used to adjust simultaneously the angular positions of the flaps.

FIGURE 7 is a fragment of FIGURE 2 showing a modified flap construction.

FIGURE 8 is a sectional view taken along the line VIII—VIII in FIGURE 7.

FIGURE 9 is a fragment of FIGURE 2 showing a modified construction including an inlet vane control.

FIGURE 10 is a fragment of FIGURE 2 showing an alternate drive mechanism.

For the purpose of convenience in description, the terms "inlet" or "upstream" and "outlet" or "downstream" will have reference, respectively, to the left and right ends of the in-line fan construction, as appearing in FIGURES 1 and 2. The terms "inner," "outer" and words of similar import will have reference to the geometric center of said in-line fan construction and parts thereof.

### General construction

The objects and purposes of this invention, including those set forth above, have been met by providing a fan construction including a cylindrical housing which is connectible at the opposite ends thereof to cylindrical ducts or the like for the purpose of selecting the source from which air is drawn and the zone into which the air is moved by the fan construction of the invention. A centrifugal impeller is rotatably supported concentrically within the housing by bearing means disposed within an annular shell which extends downstream from the impeller. An inlet cone is preferably arranged to communicate with the inlet side of the impeller, and curved, air straightening vanes are provided for their conventional purposes downstream of the impeller and also to support the annular shell.

A plurality of flaps are mounted upon the inner surface of the housing at uniform intervals therearound so that they extend toward, but are spaced a substantial distance from, the inlet side on the impeller. The flaps are arranged and located so that they substantially increase the performance of the impeller when it is rotated at a conventional speed.

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The in-line fan assembly 10 (FIGURES 1 and 2) comprises a substantially cylindrical fan housing or casing 11 which preferably has exterior annular flanges 12 and 13 secured to or integral with the opposite axial ends thereof for the purpose of connecting said housing to similar flanges 16 and 17 on inlet and outlet ducts 18 and 19, respectively, in a conventional manner. The fan housing 11 has at its inlet end an annular end wall 22 having an integral, inwardly extending and converging, inlet cone 23 defining an inlet opening 24.

An annular shell or wall means 26 (FIGURE 2), which may be cup-shaped, is concentrically disposed within the housing 11 and spaced from the inlet cone 23 a distance approximately slightly greater than the axial extent of the centrifugal impeller 27. The shell 26 has a substantially radially disposed end wall 28 at the upstream end thereof and a peripheral wall 29 which is concentric with, spaced from and diverges downstream with respect to the inner surface 32 of the fan housing 11. The upstream end of the peripheral wall 29, which merges by an arcuate surface with the end wall 28, is preferably somewhat larger in diameter than the diameter of the adjacent back plate or rear shroud 33 on the impeller 27.

The shell 26 (FIGURE 2) is supported upon and within the fan housing 11 by a plurality of spaced and curved air-straightening vanes 34 which are secured to and extend between the peripheral wall 29 and the inner surface 32 of the fan housing 11 near to, but spaced from, the upstream end of said shell. A plurality, such as 3, support rods 36 (FIGURE 2) are secured to and extend between the shell 26 and the housing 11, preferably near the downstream end thereof, if they are necessary. The upstream ends of the vanes 34 are preferably curved away from the direction of the circumferential movement of the impeller, as indicated by the arrow W in FIGURE 3. This curvature in the vanes 34 is carefully preselected in terms of the characteristics of the impeller and its rotational speed so that the upstream edge portions of the vanes 34 are approximately parallel with the movement of the air discharged by the impeller 27 as it meets the vanes 34. Thus, a minimum of loss is experienced by the straightening operation performed by the vanes 34, whereby the air departs from the downstream edges of the vanes 34 in a direction substantially parallel with the central axis of the fan housing 11.

The amount of divergence between the housing 11 and shell 26 in the downstream direction is approximately 7 degrees in this particular embodiment. It has been known in the past that a 7 degree angle of divergence will minimize losses due to turbulence produced by skin or boundary layer friction without producing corresponding losses due to separation of the air being moved. However, insofar as I am aware, it was not known that this angular relationship would also apply where the air is moved into an annular passageway, or where such air is being discharged with a major circular component of movement in a direction transversely of the lengthwise extent of the diverging passageway. After experimentation with different angular relationships, it was found that the 7 degree angular relationship is at least highly satisfactory with the improved construction embodying the instant invention.

A pair of bearing supports 37 and 38 (FIGURE 2) are mounted within and extend substantially diametrically across the shell 26, hence the peripheral wall 29 thereof. A pair of bearings 41 and 42 are mounted upon the supports 37 and 38, respectively, preferably so that they are concentric with the central axis of the shell 26. The bearing 41 is adjacent the end wall 28 which is secured to the support 37 by the brackets 43 and 44 (FIGURE 5).

A shaft 46 (FIGURE 2) is rotatably supported by the bearings 41 and 42 so that one end thereof extends through a central opening 47 in the end wall 28 for co-axial connection to the hub 48, which is secured to the back plate 33 of the impeller 27 in a substantially conven-

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tional manner. The other end of the shaft 46 supports a pulley 51 which is connected by the belt 52 to the pulley 53 on the shaft 54 of the motor 56.

The peripheral wall 29 of the shell 26 and the fan housing 11 are provided with openings 57 and 58, respectively, which are interconnected by a sleeve 59 through which the belt 52 extends between the pulleys 51 and 53. The motor 56 is mounted upon the external surface of the fan housing 11 adjacent the opening 58.

As an alternate construction, the motor 56 may be mounted, as shown at 56a in FIGURE 10, within the shell 26 upon the support 37 so that the motor shaft extends through the opening 47 and thereby directly supports the impeller 27.

The impeller 27, in this particular embodiment of the invention, has an inlet ring or intake shroud 62 which converges away from the back plate 33 to define an inlet opening 63. In this embodiment, the small end of the ring 62 is slightly larger than, and is telescoped over, the small end of the inlet cone 23 in a substantially conventional manner.

A plurality of blades 64, which are arranged and constructed in this embodiment to provide a nonoverloading characteristic, are secured to and extend between the peripheral portions of the inlet ring 62 and the back plate 33, also in a substantially conventional manner. The impeller or wheel 27, which is substantially spaced from and concentric with the inner surface 32 of the fan housing 11, is preferably spaced somewhat from the shell 26.

A plurality of flaps 66 (FIGURES 2 to 5, inclusive), which are preferably flat and thin, are mounted upon the inner surface 32 of the housing 11 preferably in radial alignment with the radially outer edge portion 67 of the inlet ring 62. Said flaps 66 are preferably of substantially uniform size and shape, they are preferably uniformly spaced around the inner surface 32 between two parallel planes disposed on opposite sides of said outer edge portion 67, and they preferably extend substantially radially inwardly from said housing 11 about half the distance between the housing 11 and the impeller 27. However, it will be recognized by persons skilled in this field that, depending upon the specific structural and operating characteristics of the particular type of centrifugal impeller 27 used in any given installation, the size, shape, radial extent and precise axial locations of the flaps 66, with particular respect to the location of the impeller 27, may be varied somewhat without departing from the scope of the invention.

In a preferred embodiment, the flaps 66 are secured to radially extending pins 68 (FIGURES 2 and 6) each of which supports externally of said housing 11 a crank 69. The several cranks 69 may in turn be connected to a control ring 72 which encircles the fan housing 11 adjacent said pins 68. An annular guide member 73 may be secured upon the fan housing 11 adjacent the control ring 72 for the purpose of retaining and guiding the movement of, the ring 72. Any type of manually operable linkage, not shown, may be utilized to effect rotational movement of the ring 72, whereby the flaps 66 are simultaneously rotated around radii of the housing 11.

It has been found through experimentation that the flaps 66 operate efficiently with the type of construction and impeller disclosed herein when they are pivoted around their pins at a slight angle (FIGURE 3), such as from about 15° to about 35°, to a plane including the axis of their respective pin and the impeller. In a preferred embodiment, the downstream edges of the flaps 66 were ahead of their upstream edges, in the direction of movement of the periphery of the wheel 27 as identified by the arrow W in FIGURE 3, and the above-mentioned angular relationship was set at 25 degrees.

While the number of flaps 66 may be varied over a substantial range, depending upon the size and other characteristics of the fan assembly 10, it has been found that a

fan assembly 10 of average size operates effectively with 16 flaps 66.

However, it has been found that quantities of flaps from less than 16 up to as many as 32 can be used effectively and, although a certain number of said flaps may operate most effectively under specific conditions, any quantity of flaps within this approximate range materially improves the performance of the fan assembly over such performance where there are no flaps at all.

#### Operation

When the impeller 27 is rotated by the shaft 46 in response to energization of the motor 56, air is drawn through the inlet cone 23 and inlet ring 62 and thereafter discharged radially by the blades 64 in a substantially conventional manner. That is, a major portion of the air or other fluid discharged by the impeller flows downstream between the casing 11 and the shell 26, and a minor portion of such air flows into the swirl chamber encircling the inlet ring 62 and inlet cone 23. However, the flaps 66 materially reduce the turbulent conditions which previously existed in the zone occupied by said flaps between the divergent paths of air flow emanating from the impeller adjacent the inlet ring 62. Much if not most of this turbulent air is now induced by the flaps 66 to join with the major air flow toward the discharge end of the fan housing 11, whereby the performance of the fan assembly 10 is increased without increasing the power input.

At the same time, the flaps 66 do not disturb the natural vortex which rotates with and adjacent the inlet ring 62 and around the inlet cone 23. By appropriate movement of the control ring 72, the angular positions of the flaps 66 can be adjusted if the need should arise. However, under most circumstances the flaps 66 will be fastened in their optimum positions when the fan assembly is manufactured, and no further adjustment will be required.

As illustrated in FIGURES 7 and 8, a modified fan assembly 80 comprises a fan housing 81 in which an impeller 82 is rotatably supported in substantially the same manner set forth above with respect to the fan assembly 10. However, in the fan assembly 80, the purposes of the invention are achieved by concentrically supporting a substantially annular rim 83 in spaced relationship within the housing 81 by means of the plates 84. In this particular embodiment, the plates may be substantially parallel with a plane including the rotational axis of the impeller 82, or they may be disposed at a slight angle to such a plane, as discussed above with respect to the flaps 66. However, the number of plates 84 can be less, where the rim 83 is provided, than the number of flaps 66 without the rim. In this regard, it has been found that, depending upon the diameter of the housing and impeller of the fan assembly involved, the number of plates 84 required may vary, as in the case of the number of flaps 66.

In general, it has been found that the rim 33 should be disposed between two parallel planes substantially perpendicular to the rotational axis of the impeller 82 and located in approximately the same positions as the two planes between which the flaps 66 extend. That is, such planes are preferably located on opposite sides of the peripheral edge of the inlet ring 85.

The modified construction shown in FIGURE 9 illustrates the use of an inlet vane control 90 within an inlet cone 91 adjacent an impeller 92, and these latter two parts may be substantially identical with the cone 23 and impeller 27, respectively. By means of the inlet vane control 90, which may be of a substantially conventional type, the performance, hence the output, of the associated fan assembly may be efficiently controlled.

Although particular preferred embodiments of the invention have been disclosed above for illustrative purposes, it will be understood that variations or modifications of such disclosure, which come within the scope of the appended claims, are fully contemplated.

What is claimed is:

#### 1. A fan construction comprising:

a substantially cylindrical housing having a central inlet opening at one end and an annular discharge opening at the other end, said discharge end being axially spaced from said inlet opening;

a centrifugal impeller disposed within said housing, said impeller having an arcuate intake shroud communicating with the central intake opening and defining a forward swirl chamber closed at the said one end, the outer periphery of said intake shroud being radially spaced inwardly of the cylindrical wall of the housing, said impeller having a rear shroud axially spaced from said intake shroud and having an outer periphery spaced radially inwardly from said wall of the housing;

blades supported between said shrouds and having outer periphery edges extending between the shrouds adjacent the periphery thereof;

annular wall means supported within said housing and spaced radially inwardly from the cylindrical wall and extending axially rearwardly from adjacent to said rear impeller shroud, said annular wall means and said cylindrical wall defining an axially extending chamber terminating in said discharge opening;

shaft means and means supporting shaft means within said housing, said shaft means rotatably supporting the impeller;

means on said shaft means to rotate said impeller whereby the centrifuged fluid engaging said cylindrical wall of said housing divides into a major portion flowing into said annular chamber and a minor portion flowing into said swirl chamber;

said cylindrical housing wall having a plurality of short, substantially flat and substantially radially inwardly extending flaps mounted thereon, each of said flaps having a free inner edge that terminates spaced radially outwardly of the blades' outer edges, each of said flaps having a pair of axially spaced end portions one thereof extending into said swirl chamber and the other portion extending only over that portion of the outer edges of the blades adjacent the intake shroud, said flaps being so positioned to reduce turbulence in the zone of separation of the centrifuged fluid as it flows into said swirl chamber, and into said annular chamber from the zone of separation of said major and minor portions of fluid flow.

2. A fan construction according to claim 1, wherein said annular wall means diverges with respect to said wall of said housing away from said impeller at an angle of from 5° to 10°;

wherein said annular wall means is mounted coaxially within said cylindrical wall means by a plurality of elements secured to and extending between said housing and said annular wall means at intervals circumferentially thereof;

wherein said annular wall means has an annular end wall adjacent to, spaced from and substantially parallel with said rear shroud; and

wherein said flaps are of uniform size and shape, each flap being positioned at an angle of from 55° to 75° with respect to a plane perpendicular to the rotational axis of the impeller and passing through said flaps, the edges of said flaps nearest said annular wall means being ahead of the opposite edges of said flaps in the direction of rotation of said impeller.

3. A fan construction according to claim 1, wherein a cylindrical ring is secured to said inner edges of said flaps and extends axially between two planes substantially defined by the axial edges of said flaps, said ring being spaced radially outwardly from the outer peripheral edge of said impeller.

4. A fan construction according to claim 1, wherein said flaps are of uniform size and shape and are disposed at

substantially uniform intervals circumferentially of said housing;

wherein each of said flaps includes means pivotally supporting each flap for movement around an axis extending radially of said impeller; and  
control means mounted upon said housing and connected to each of said flaps for effecting simultaneous pivotal movement of said flaps around their respective axes.

5. A fan construction according to claim 1, comprising: bearing means mounted upon and within said annular wall means and rotatably supporting said shaft means; an electric motor having a shaft and being secured upon the outside of said housing; and

means defining openings through said wall means and said housing in radial alignment between portions of said shaft means and said motor shaft, said means on said shaft means comprising pulley and belt means connecting said motor shaft to said shaft means.

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20 KARL J. ALBRECHT, *Primary Examiner*.  
JOSEPH H. BRANSON, JR., *Examiner*.