

United States Patent

Ball et al.

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[45] Aug. 15, 1972

[54] **CENTRIFUGAL FAN WITH IMPROVED CUT OFF MEANS**

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[22] Filed: **May 4, 1970**

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[21] Appl. No.: **34,182**

[52] U.S. Cl.**415/53**, 415/206, 415/DIG. 1, 415/144

[51] Int. Cl.**F04d 17/08**, F04d 29/40

[58] Field of Search.....415/204, 206, 219, 53, 54, 415/119, DIG.1, 212, 144

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[57] **ABSTRACT**

A centrifugal fan having a fan wheel with a fluid inlet at the rotational axis of the fan wheel and a discharge outlet spaced radially outwardly of the inlet in a plane substantially parallel to the axis is provided with increased efficiency and discharge flow by controlling the flow of fluid across a cut off means which peels fluid from the fan wheel for discharge through the outlet. More specifically, some of the fluid moving across the cut off means is withdrawn therefrom through a passageway extending to a region of lower pressure to reduce the thickness of a fluid boundary layer at the cut off means and thereby provide an increased cross sectional area with decreased frictional losses. Preferably, the withdrawn fluid is recirculated within the centrifugal fan.

3 Claims, 12 Drawing Figures

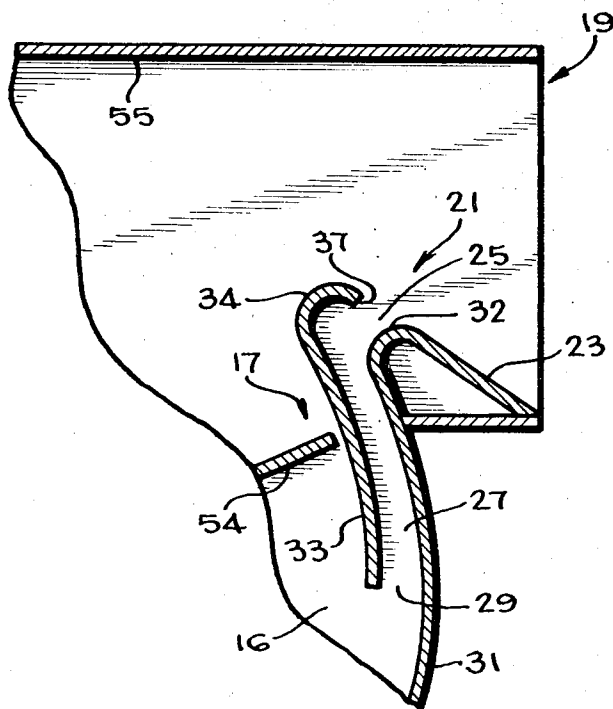


FIG. 1

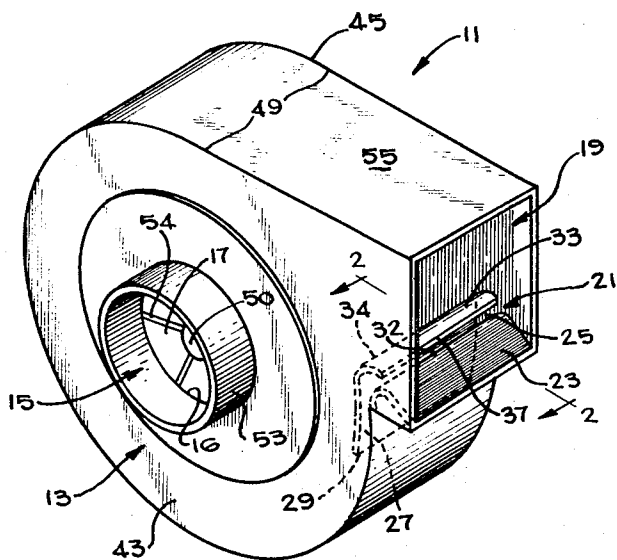


FIG. 6

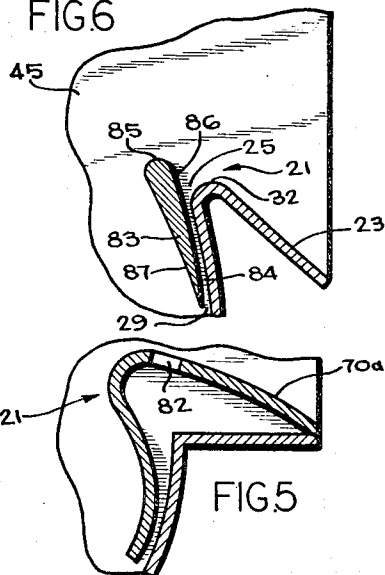


FIG. 5

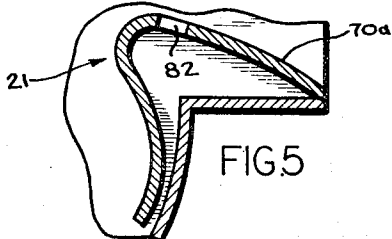


FIG. 4

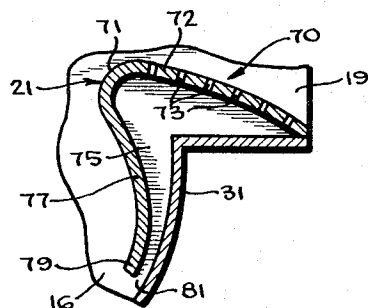


FIG. 2

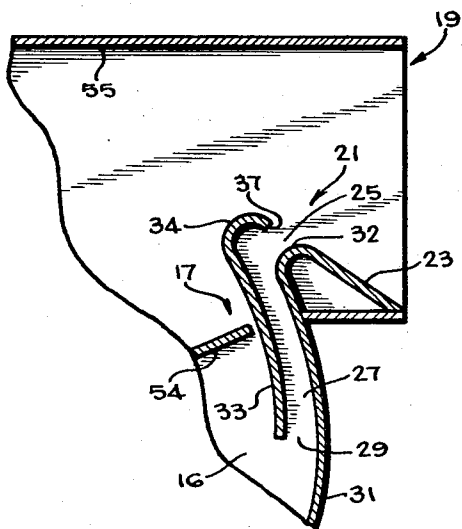
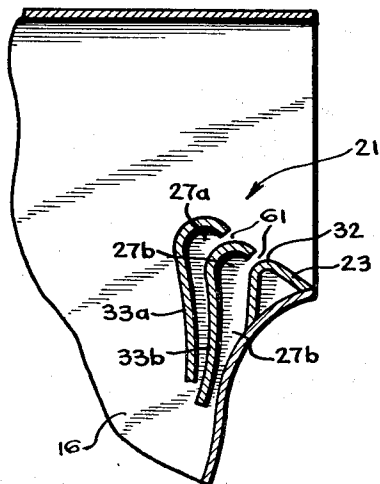


FIG. 3



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FIG.12

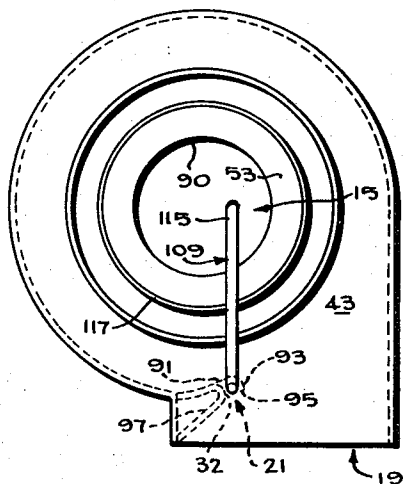


FIG.10

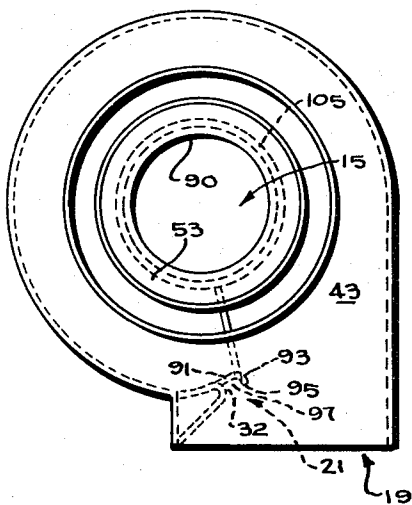


FIG.8

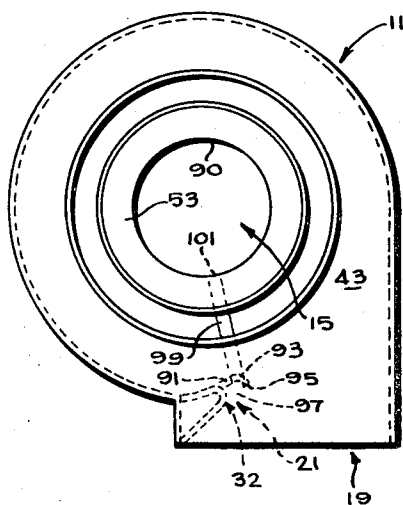


FIG.11

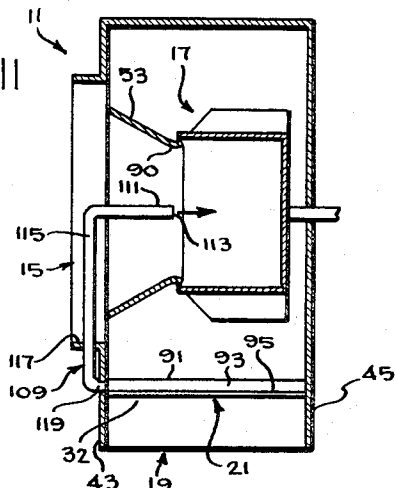


FIG.9

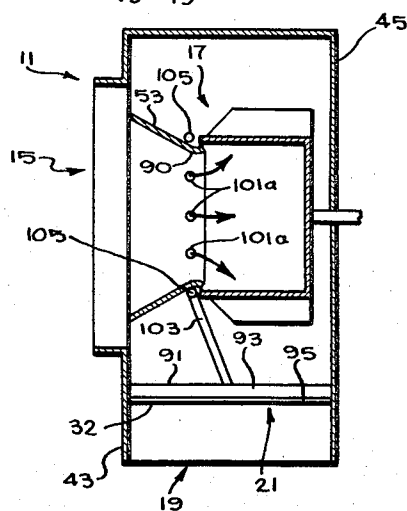
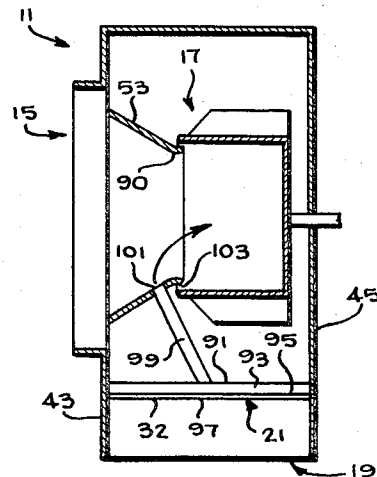


FIG.7



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CENTRIFUGAL FAN WITH IMPROVED CUT OFF MEANS

This invention relates to centrifugal fans which have a fan wheel mounted within a fan housing for rotation about an axis through the center of the fan wheel and which propel fluid entering the housing at an axial inlet radially outwardly and circumferentially to a discharge outlet which is spaced radially from the fan wheel axis.

In such centrifugal fans, some of the fluid being propelled by the fan wheel tends to follow the fan wheel and recirculate by moving past the discharge outlet with the wheel. To divert fluid from recirculating with the fan wheel, a cut off in the form of a pointed blade is positioned within the fan housing adjacent the periphery of the fan wheel to peel fluid therefrom and thereby increase the volume of fluid flowing to and through the discharge outlet.

Centrifugal fans with cut offs are well known and their operating characteristics and efficiencies are usually published and fairly well established. In accordance with the present invention, the efficiency of commercially available and acceptable kinds of centrifugal fans may be increased by a more efficient utilization of the cut off and the discharge outlet. Also, as will be explained, existing centrifugal fans may be modified to achieve increased efficiency at very little additional cost.

Accordingly an object of the invention is to provide increased efficiency, as contrasted with the prior art, for centrifugal fans of the foregoing kind.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of a centrifugal fan embodying the novel features of the invention;

FIG. 2 is a fragmentary cross-sectional view taken substantially along the line 2—2 of FIG. 1 showing a cut off means for withdrawing fluid from a fluid boundary layer on a surface of the cut off means;

FIGS. 3, 4, 5 and 6 illustrate further embodiments of cut off means for practicing the invention; and

FIGS. 7 and 8, FIGS. 9 and 10, and FIGS. 11 and 12 illustrate further means for withdrawing boundary fluid from the cut off means.

As shown in the drawings for purposes of illustration, the invention is embodied in a centrifugal fan 11 having an exterior housing 13 with an axially located inlet 15 through which fluid flows into an internal housing chamber 16 and into the center of a rotatable fan wheel 17 which impells the fluid radially outwardly and circumferentially within the chamber 16 to a discharge outlet 19 for the fan. At the discharge outlet 19, a cut off means 21 peels some of the fluid being carried by the fan wheel circumferentially in a direction past the cut off and diverts this peeled fluid outwardly through the discharge outlet opening.

A commercially significant increase in efficiency may be obtained by withdrawing some of the fluid from the cut off means 21 to control boundary layer effect resulting from the fluid changing direction and experiencing a frictional drag across the stationary surface of a wall 23 of the cut off means. More specifically, the diverted fluid nearest the wall 23 is subject to shearing forces which cause its velocity to be reduced

relative to the outer or free-stream velocity at the center of the outlet 19 and this reduced velocity fluid constitutes a boundary layer which effectively decreases the cross-sectional area of the outlet 19 available for free-stream velocity flow. By extracting fluid from the cut off means 21 adjacent the wall 23, the boundary layer effect is controlled to the extent that a greater cross-sectional area with decreased frictional losses is available for higher velocity fluid flow whereby the efficiency of the centrifugal fan is increased. Preferably, the fluid from the boundary layer is extracted through an opening 25 adjacent the cut off means 21 and flows through a passageway 27 to discharge at an opening 29 which is at a region of lower pressure than the pressure at the opening 25. In this manner, the thickness of the boundary layer is reduced, boundary layer separation is avoided, and less turbulent and more laminar flow is achieved across the cut off means.

As will be explained, various means for achieving boundary layer control at the cut off means 21 may be utilized. One inexpensive and simple means for use with centrifugal fans having a conventionally shaped cut off pointed nose 32 is to interpose a plate or wall 33 in the space between the fan wheel 17 and the housing wall 31 adjacent the pointed nose 32 to cooperate therewith to define the opening 25 and also to define the passageway 27 wall 31 for discharging extracted fluid for recirculation at a location circumferentially past the outlet 19. Preferably, the upper end 34 of the interposed plate 33 is curved toward the outlet 19 to provide a pointed nose and this curved nose terminates at an edge 37 spaced from the pointed nose 32 and defines therebetween a transversally extending, slotted opening 25. Thus, fluid extracted at the opening 25 will flow between the plate 33 and the wall 31 to discharge in the chamber 16 for recirculation by the fan wheel.

Referring now in greater detail to the illustrated centrifugal fan 11, the housing 12 is generally convolute in shape and is formed by a pair of spaced side walls 43 and 45 which are joined at the outer edges 49 thereof to a convolute or spirally shaped, circumferential intermediate wall 31 which is joined along the edges of the side walls to define the interior chamber 16 which has a convolute or spiral shape about a central axis 50 through the fan wheel 17. Attached to the side wall 43 at the inlet 15 is a diffuser 53 which is in the form of a hollow cylinder fastened at one end to the side wall 43 and projecting therefrom. The diffuser 53 defines a circular cross sectioned inlet 15 located at the axis of the fan wheel 17. The fluid, which is usually air or a gas bearing some other particulate matter, flows through a duct (not shown) which is connected to the diffuser 53 and then inwardly into the housing at the rotational axis of the fan wheel 17.

The fan wheel is a conventional wheel which may take several shapes depending upon the fluid and the velocity at which the fluid is to be delivered. A typical fan wheel will have two annular plates spaced axially from each other with generally radially disposed vanes 54 fastened to and disposed between these annular plates. The fan wheel is attached to a shaft (not shown) which is driven by a suitable motor drive which is also not shown. The fan wheel 17 is disposed in the housing so that the tips of blades 54 are usually at their closest

point to the circumferential housing wall 31 at the cut off means 21 and from this point the housing wall 31 diverges outwardly from the blade tips until reaching the upper outlet wall section 55 which extends outwardly from the chamber 16 and is substantially parallel to a tangent of the fan wheel 17 to define an upper duct wall for the outlet 19.

The outlet 19 also has side wall sections which are integral with the side walls 43 and 45 and extend vertically between the upper duct wall section 55, and the cut off wall 23 which forms a lower wall for the outlet duct. The cut off wall 23 is inclined relative to the upper duct wall 55 and diverges downwardly and outwardly from the pointed nose 32. The cut off means 21 is placed as close to the periphery of the fan wheel as possible without generating noise or a whistle, and extends transversely from and is secured to side walls 43 and 45.

Most of the incoming fluid flows outwardly along the fan blades 54 from the axis of the fan wheel 17 toward the tips of the blades while the fan blades are in the process of carrying the fluid in a circumferential direction toward the outlet. Most of the radially outwardly moving fluid flows into the convolute shaped space between the fan wheel and housing and exits the fan in a plane parallel to the axis 50 at the discharge outlet 19 while some of the fluid, which otherwise would follow the fan blades past the outlet 19 is diverted from the fan wheel by the cut off means and directed through the outlet. Of course, some of the fluid recirculates with the fan wheel.

In accordance with the invention illustrated in FIGS. 1 and 2, most of the fluid diverted by the cut off means flows across the opening 25 and exits through the outlet because the opening is relatively narrow such as, for example, three-eighths inch and the pressure differential between the opening 25 and the discharge opening 29 is not such as to induce a high velocity flow rate. However, sufficient fluid is extracted to reduce the thickness of the boundary layer whereby the cross-sectional area available for free-stream velocity is increased at the outlet 19. More specifically, the rounded nose 34 serves as the initial cut off surface for the fluid being peeled from the fan wheel and instead of a higher pressure, lower momentum fluid build up on wall 23 in the form of an appreciably thick boundary layer causing the high velocity flow to be spaced appreciably above the wall 23, the high velocity flow is able to be more closely adjacent the wall 23. Even though some fluid is being deliberately recirculated through the passageway 27, the overall efficiency may be increased by a commercially significant amount such as, for example, 2 percentage points or more.

The particular manner in which the air is withdrawn from the surface of the cut off means 21 may be varied, for example, rather than a single slot defining the opening 25, the opening 25 may be constituted by a pair of parallel slots 61, as illustrated in FIG. 3 to provide fluid removal at several locations spaced in the direction of fluid outflow. In this instance, a pair of plates 33a and 33b similar to the plate 33 above described in connection with FIGS. 1 and 2 are positioned in the space between the fan wheel 17 and the nose 32 of the wall 23 to provide a pair of passageways 27a and 27b to conduct fluid to the chamber 16 for recirculation.

In the embodiment illustrated in FIG. 4, the cut off means 21 is in the form of a perforated cut off plate 70 which has a nose 71 extending closely adjacent to the periphery of the fan wheel 17 to peel fluid therefrom and for directing fluid to and through the outlet 19. An upper section 72 of the cut off plate 70 is provided with rows of apertures 73 opening into a passageway 75 formed between a downturned section of first portion 77 of the cut off plate and the adjacent wall 31 of the housing which constitutes a segment of a spiral. Thus, a pressure differential between the fluid in the boundary layer on the section 72 and in the chamber 16 at an end 79 of the section 77 causes fluid to flow through the apertures 73 into the passageway 75 and discharge at the outlet 81 at the terminal end 79 of the section 77. Thus, the boundary layer thickness is thinned in both the longitudinal and transverse directions across the section 72 of the cut off plate so that the high velocity stream flow may follow more closely the contour of the section 72. The embodiment of the invention illustrated in FIG. 5 is generally similar to that illustrated in FIG. 4 except that a cut off plate 70a similar to cut off plate 70, described in connection with FIG. 4, is provided with a continuous transverse slot 82 rather than rows of apertures 73. Thus, in both of the embodiments of the invention illustrated in FIGS. 4 and 5, the boundary layer control is achieved by a cut off means using but a single one piece cut off plate with slots or perforated openings which allow air to be extracted from the boundary layer for return to the chamber 16 with the result that the fast velocity discharging air is pulled down to cling to the sloping section 72 of the cut off plate rather than being separated from it whereby more full use of the fan outlet area is achieved.

In another form of the invention, the cut off means 21 includes an air foil 83 which is interposed between the nose 32 of the cut off plate 23 and the periphery of the fan wheel 17. The air foil 83 defines a passageway 84 with the wall 31 of the housing with an upper slot shaped opening 25 formed at the top of the passageway and a lower discharge slot 29 at the lower end of the passageway. The air foil is fastened to the housing side walls 43 and 45 in a suitable manner. The air foil 83 is formed with an upper rounded end 85 and a curved surface 86 facing the housing wall 31 with a substantially flat surface 87 facing the fan wheel. Thus, air flowing along the curved surface 86 must take a longer path than air flowing along the surface 87 in the usual manner of an air foil with the result of higher velocity, lower pressure flow occurs in the passageway 27. Thus, an additional pressure differential is produced within the passageway 84 by the air foil to assist the above-described pressure differential in extracting fluid from the cut off means. It will be appreciated that other manners of generating a pressure differential may be used and that other passageways and other regions of relatively low pressure than that described may be used to extract fluid to control the boundary layer formation and fall within the purview of the invention.

In the embodiments of the invention illustrated in FIG. 7-12, the region of lower pressure to induce a flow of boundary layer fluid is located at the fan inlet 15 rather than a point immediately downstream of the cut off means 21 as described in connection with the embodiments of the invention illustrated in FIGS. 1-6.

More specifically, the region of lower pressure is located in the fan inlet at which there is a high velocity, lower pressure fluid flow region particularly at an encircling narrowed wall defining a narrowed throat 90 for the diffuser 53. In these embodiments, there is sufficient pressure differential between opposite ends of a closed passageway between the fan inlet 15 and the cut off means 21 to cause the fluid from the boundary layer to flow through the passageway and discharge into the fan inlet for recirculation.

Referring now to FIGS. 7 and 8, the centrifugal fan 11 has been provided with cut off means 21 comprising the conventionally shaped cut off, pointed nose 32 and an additional plate 91 which extends upwardly and inwardly therefrom toward the fan wheel 17. The plate 91 extends laterally across the fan outlet 19 between housing side walls 43 and 45. An upper end 93 of the plate 91 is curved toward the outlet 19 to provide a nose which terminates at an edge 95 spaced from the pointed nose 32 to define therebetween a transversely extending slotted opening 97 similar to the slotted opening 25 previously described. Fluid is extracted from the boundary layer through the slotted opening 97 and flows through a passageway in a conduit or pipe 99 to discharge at opening 101 in the fan diffuser 53 within which is a region of pressure lower than the pressure in the boundary layer fluid at the opening 97. As best seen in FIG. 7, the pipe 99 opens into the slotted opening 97 generally centrally of the fan outlet 19 and extends at angle to an end 103 attached to the diffuser 53 into which the pipe opens.

The embodiment of the invention shown in FIGS. 9 and 10 is substantially the same as described in connection with FIGS. 7 and 8 except that the pipe end 103 is connected to a circular conduit or pipe 105 which encircles the throat 90 of the diffuser 53. A series of openings 101a in the diffuser 53 are in fluid communication with the inside of the encircling pipe 105 to provide a more uniform injection of the boundary fluid into the incoming fluid stream in the fan inlet for recirculation therewith.

In the embodiment of the invention illustrated in FIGS. 11 and 12, the passageway between the cut off means 21 and the region of low pressure at the fan inlet 15 is in the form of a conduit or pipe 109 having one end 111 projecting parallel to and within the fan inlet. This end of the pipe 109 terminates in an opening 113 which is at the diffuser throat and slightly offset from but adjacent to the center of the throat, as best seen in FIG. 12. The pipe end 111 is connected at a right angle bend to a straight section 115 which extends through an opening 117 in the diffuser to an elbow section 119 which projects through an opening in the side wall 43 into the slotted opening 97. Fluid in the boundary layer may be extracted, due to a pressure differential, from the slotted opening 97 in the cut off means 21 and conveyed through the pipe 109 for discharge at the pipe opening 113 which is in the fan inlet opening 15. Thus, the high velocity and low pressure region adjacent the midstream of the air inlet is used to establish, through the pipe 109, a pressure differential with the cut off means 21 to cause boundary layer fluid at the latter to flow through the pipe 109 and to be recirculated.

From the foregoing it will be seen that a centrifugal fan may be provided with increased efficiency by

withdrawing fluid at the cut off means so as to reduce the thickness of the boundary layer thereat and thereby achieve a larger effective cross section with decreased frictional losses available at the discharge outlet for high velocity stream flow. One manner of extracting the air is by providing an opening in the cut off means through which fluid may flow to a passageway extending circumferentially in the downstream direction for a short distance to a region of lower pressure. Another region of lower pressure which may be used is located at the high velocity, fluid flow at the fan inlet. Preferably, the fluid withdrawn from the boundary layer is discharged for recirculation within the fan. As disclosed, the control of the fluid boundary layer may be achieved with a number of different and inexpensive means.

While a preferred embodiment has been shown and described, it will be understood that there is no intent to limit the invention by such disclosure but, rather, it is intended to cover all modifications and alternate constructions falling within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A centrifugal fan comprising a housing having spaced side walls and a circumferential wall joined to said side walls and having a chamber therein, a fan wheel mounted for rotation within said chamber and for receiving fluid at a central axis thereof and for moving said fluid radially outward and circumferentially within said housing, inlet means for said housing chamber for admitting fluid to said fan wheel at the center thereof, an outlet duct for said housing having side walls and a top and bottom wall defining an outlet passage-way disposed substantially parallel to a tangent of said fan wheel and having a predetermined cross-sectional area available for discharging fluid, a cut off means extending from said lower wall of said outlet duct toward said fan wheel and forming with said circumferential wall of said housing a first pointed nose projecting toward said fan wheel, a plate interposed between said fan wheel and said first pointed nose and having another pointed nose projecting toward said fan wheel for peeling and directing fluid from said fan wheel outwardly across said bottom wall and through said outlet duct, said first pointed nose and said other pointed nose defining a slotted opening extending substantially between said housing side walls to admit some of the fluid peeled from said fan wheel, said interposed plate being curved downwardly and closely adjacent to said circumferential wall of said housing to define with said housing side walls a passageway for fluid flow extending from said slotted opening, and a lower end for said interposed plate spaced from said circumferential wall and defining an outlet for said passageway to discharge fluid at an area within said housing chamber which is at a pressure which will allow fluid to flow through said passageway.

2. In a centrifugal fan wherein a housing is provided which includes a pair of generally parallel side plates; wherein said side plates are interconnected by an intermediate plate formed to define a segment of a spiral commencing at a first line spaced in one direction from the geometric center of the spiral and terminating at a second line spaced from said first line by approximately two hundred seventy rotative degrees about said

geometric center of the spiral; wherein said intermediate plate includes an extension from each of said first and second lines, said extensions extending in generally parallel relation to each other in said first direction to define with said side plates a discharge opening; wherein a fan wheel is mounted within said housing for rotation about an axis an axis passing generally through said geometric center of said spiral; said fan wheel having a diameter sufficient to bring its outer periphery in close proximity to said first line of said spiral; wherein a fan inlet opening is provided in at least one of said side plates in alignment with the center of said fan wheel; and wherein a cut off is provided adjacent said first line to provide a transition from the spiral flow of air in said housing to a straight line flow of air through the fan discharge, said cut off including a first portion extending from adjacent said first line and continuing generally the curve of said spiral segment and a second portion extending from the terminus of said first portion at an acute angle to said first portion in the direction of said discharge opening, the improvement which comprises

A. means defining an elongated passageway extending circumferentially of said fan wheel along the inner surface of said spiral segment of said housing past said one line,

1. the inlet of said passageway being located adjacent said terminus of said first portion of said cut off and the outlet of said passageway being located in an area intermediate said fan wheel and said spiral segment at which the air pressure is lower than at the inlet of said passageway when the fan wheel is rotating at operating speeds so as to draw air through said passageway from adjacent the surface of said cut off and reduce the boundary layer drag at said surface,

said means defining said elongated passageway including a plate disposed within said fan housing outwardly of said fan wheel, said plate extending from adjacent said terminus of said first portion of said cut off along said first portion past said first line of said spiral segment of said housing and along a portion of said spiral segment, said plate being spaced along its length from said portion of said cut off and from said portion of said spiral segment, the end of said plate adjacent said terminus of said first portion of said cut off including a portion curled in the direction of said fan discharge, the edge of said curled portion of said plate being spaced from the terminus of said first portion of said cut off to define the inlet of said passageway.

3. In a centrifugal fan wherein a housing is provided which includes a pair of generally parallel side plates; wherein said side plates are interconnected by an intermediate plate formed to define a segment of a spiral

commencing at a first line spaced in one direction from the geometric center of the spiral and terminating at a second line spaced from said first line by approximately 270 rotative degrees about said geometric center of the spiral; wherein said intermediate plate includes an extension from each of said first and second lines, said extensions extending in generally parallel relation to each other in said first direction to define with said side plates a discharge opening; wherein a fan wheel is mounted within said housing for rotation about an axis passing generally through said geometric center of said spiral; said fan wheel having a diameter sufficient to bring its outer periphery in close proximity to said first line of said spiral; wherein a fan inlet opening is provided in at least one of said side plates in alignment with the center of said fan wheel; and wherein a cut off is provided adjacent said first line to provide a transition from the spiral flow of air in said housing to a straight line flow of air through the fan discharge, said cut off including a first portion extending from adjacent said first line and continuing generally the curve of said spiral segment and a second portion extending from the terminus of said first portion at an acute angle to said first portion in the direction of said discharge opening, the improvement which comprises

A. means defining an elongated passageway extending circumferentially of said fan wheel along the inner surface of said spiral segment of said housing past said one line,

1. the inlet of said passageway being located adjacent said terminus of said first portion of said cut off and the outlet of said passageway being located in an area intermediate said fan wheel and said spiral segment at which the air pressure is lower than at the inlet of said passageway when the fan wheel is rotating at operating speeds so as to draw air through said passageway from adjacent the surface of said cut off and reduce the boundary layer drag at said surface,

said means defining said elongated passageway including a plate disposed within said fan housing outwardly of said fan wheel, said plate extending from adjacent said terminus of said first portion of said cut off along said first portion past said first line of said spiral segment of said housing and along a portion of said spiral segment, said plate being spaced along its length from said portion of said cut off and from said portion of said spiral segment, said plate having the configuration of an airfoil in a plane normal to the axis of rotation of said fan wheel, said plate being relatively wide at that one of its ends which is disposed adjacent the terminus of said first portion of said cut off and tapering to a relatively narrow width at its opposite end.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,684,396 Dated August 15, 1972

Inventor(s) Donald H. Ball and Henry Kawulski

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In The Claims:

- Column 7, line 7, delete second occurrence of "an axis";
- Column 7, line 16, after "discharge" insert --opening--;
- Column 7, line 47, after "discharge" insert --opening--;
- Column 8, line 19, after "discharge" insert --opening--.

Signed and sealed this 23rd day of January 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents