Feb. 20, 1968 J. R. ERWIN 3,369,773

SWEPT VANE LOUVER SYSTEM

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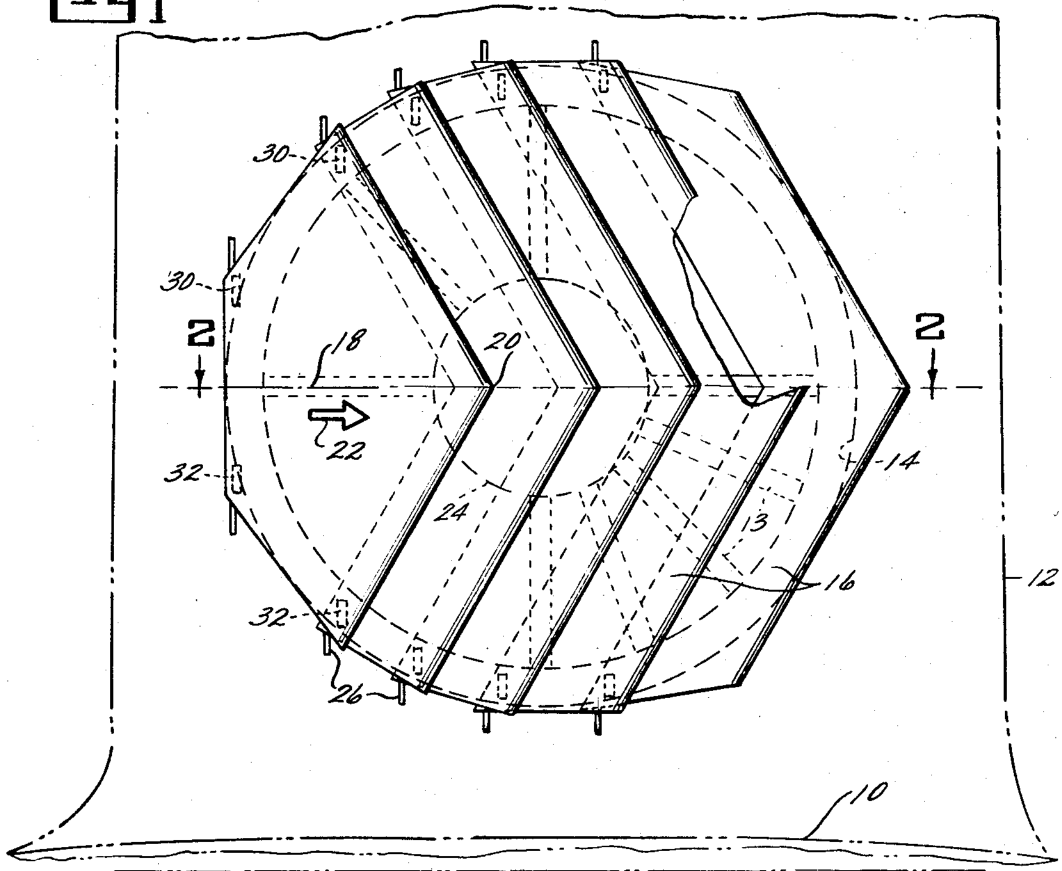
Fig 1



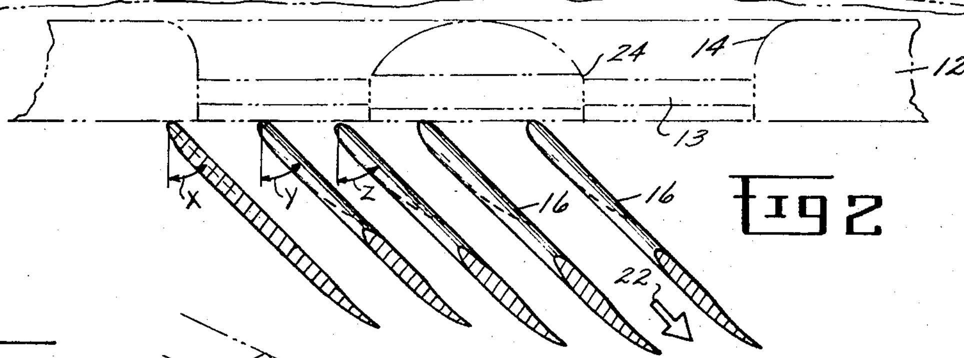


Fig 2

Fig 3

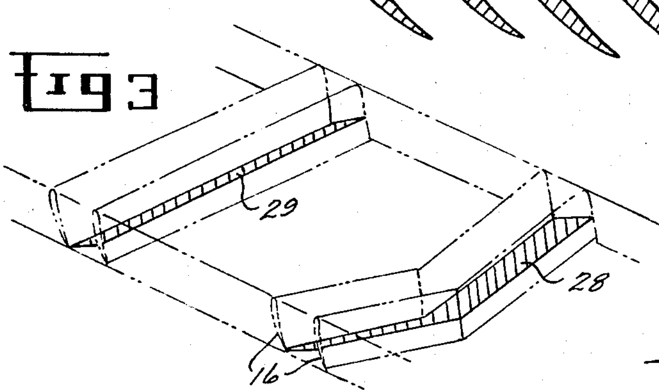


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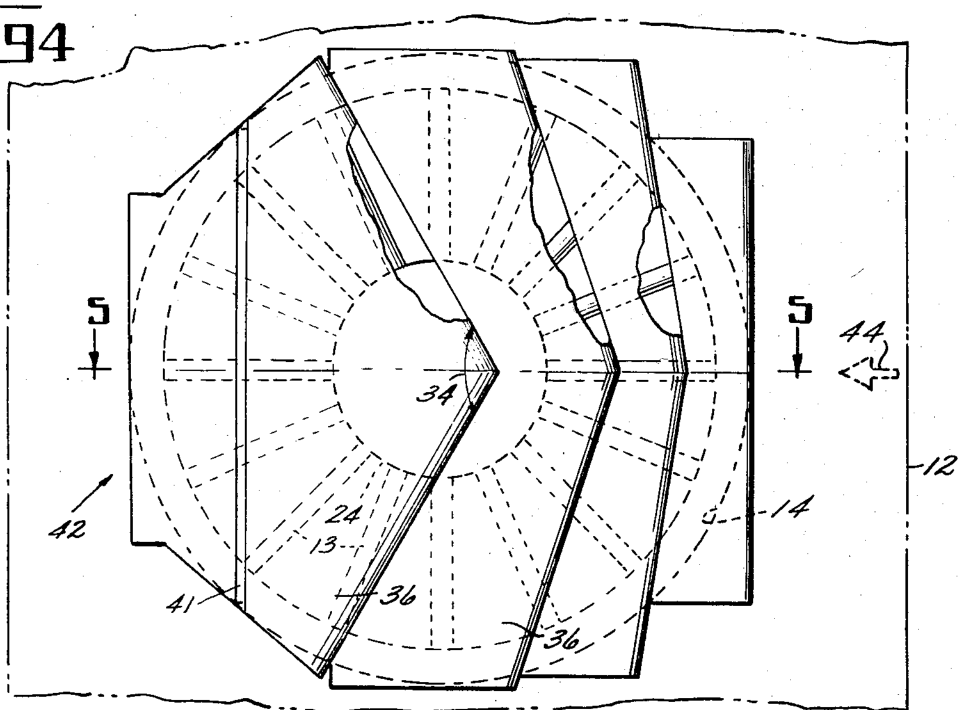
FIG. 4



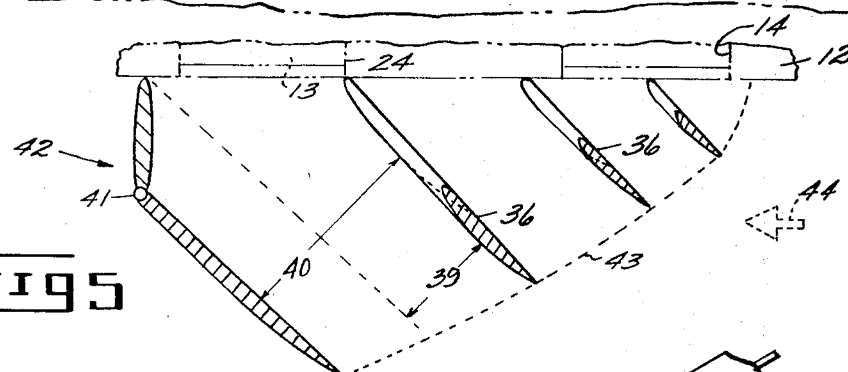


FIG. 5

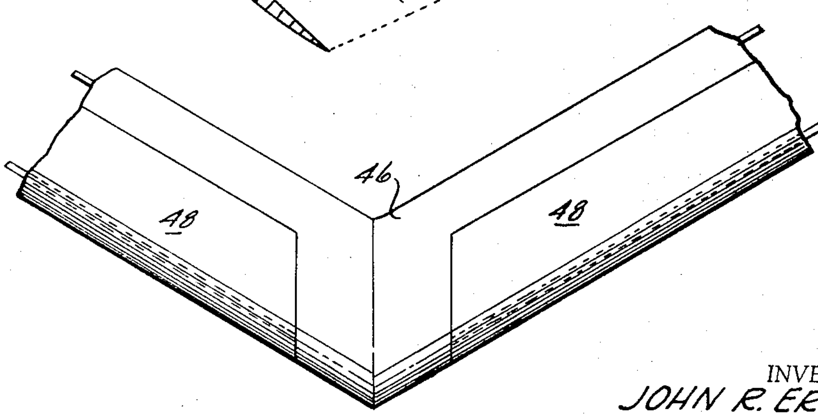


FIG. 6

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SWEPT VANE LOUVER SYSTEM

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ABSTRACT OF THE DISCLOSURE

The invention is directed to a louver system for vectoring the flow through aircraft lift fans. It uses swept louvers as opposed to straight and this permits a constant flow area over a large vectoring operating range and is intended to replace vectoring cascades of vanes that are rotated below lift fans.

The vane louver system to be described herein is applicable to either inlets or outlets of openings through which fluid passes but will be described primarily in connection with a fluid outlet as a matter of convenience in illustration.

In VTOL or STOL aircraft it is desirable to vector the exhaust from engines such as direct lift or others or from lift fans in the aircraft. The vane louver system herein is primarily directed to a more efficient means of vectoring the fluid discharge through an angle from the vertical to a relatively large angle for forward propulsion when applied to aircraft of the above type. In other words, the vane louver system herein is an effective vectoring arrangement regardless of the source of the fluid. For convenience, it is best described in connection with the lift fan type as shown in U.S. Patent 3,176,934 regardless of the position of the lift fans. Such an aircraft as described in the patent, is intended to take off in normal fashion using the conventional runways or, when required, it may lift vertically or with a short takeoff. In such an application the lift fans are able to produce about 60% of the vertical lift as horizontal thrust. This limitation is due to two factors. One of these is the back pressuring on the fan as the exit louvers are vectored rearward beyond about 40°. The second is the performance loss of the louver vanes themselves as they are required to operate at high angles of attack.

As seen in the above patent, the fan exit louvers presently used for thrust vectoring are placed close to the fan stators. These exit louvers are generally straight parallel venetian-blind types of louvers that pivot about their span on axes located just below the fan stators. This satisfactorily closes the surface opening through which the fluid moves and is adequate for a limited range of vectoring. Beyond about 40° of vectoring by the louvers from the vertical, the pressure drop produced is objectionable. This occurs because as they are turned rearward the louvers close down and reduce the exit area. The reduction of effective exit area throttles the fan significantly and the total force produced by the fan is reduced.

If the entire cascade of louvers were swung down from one end and then made longer, it can be seen that the effective area could be maintained the same and greater horizontal thrust vectoring could be obtained. In other words, a greater flow area would be available. Of course, the disadvantages of this arrangement are the mechanical complexities and the lowering of such a large device as well as the means to turn the individual louvers. An additional disadvantage is the leakage out of the side from the fan stream.

The present invention is directed to obtaining the same increased vectoring effect without the need for dropping the cascade structure. All the advantages of a dropped cascade are obtained without the disadvantage of me-

chanical complexity and the necessity for an additional duct to contain the flow through the cascades and prevent spillage out the sides.

The main object of the present invention is to provide a vane louver system which minimizes, if not eliminates, the decrease in exhaust area when the individual louvers are actuated over a large operable range and does this by employing swept vanes.

Another object is to provide a vane louver system which may take numerous forms of swept vanes to provide an area increase by adding perimeter to the vane system.

A further object is to provide such a vane louver system which avoids the loss normally inherent in conventional systems by presence of a centerbody because the invented system makes use of the centerbody area to add to the additional area obtained by the swept feature.

Briefly stated, the invention is directed to a swept vane louver system, such as a thrust vectoring system, which includes an opening through which fluid may pass. A cascade of airfoils is provided over the opening and each airfoil is symmetrically swept back from an apex at substantially the midspan thereof. Hinge means are provided to connect each airfoil at its ends in the opening to position the airfoils in flat closing position over the opening. Means are provided to rotate the airfoils away from the surface in which the opening is located to minimize the decrease in discharge area when the airfoils are rotated with their apexes pointing downstream to vector the fluid from the opening. Various modifications are provided wherein each airfoil may be moved a different angular amount from its adjacent airfoil and wherein the span and chord as well as the sweep angle of each airfoil may differ from its adjacent airfoil. Additionally, to correct angle of attack problems, the camber of each airfoil may be varied on symmetrical portions adjacent the midspan.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed the invention will be better understood from the following description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a partial view of a swept vane louver system as used in a lift fan installation;

FIGURE 2 is a partial cross-sectional view on line 2—2 of FIGURE 1 with the louvers opened and showing the lift fan in phantom;

FIGURE 3 is a diagrammatic partial perspective view illustrating the area increase obtainable;

FIGURE 4 is a view similar to FIGURE 1 showing a modification of the swept vane louver system;

FIGURE 5 is a partial sectional view taken on line 5—5 of FIGURE 4 with the louvers opened; and

FIGURE 6 is a partial plan view of a modified swept system employing variable camber louvers.

For convenience, the invention herein will be described as it might be used in connection with the exit louver system as used in the above mentioned Patent 3,176,934. It should be noted however that it is not confined to a circular opening nor is it confined to exit louvers but may equally be used in an inlet louver system. However, for ease of description and illustration, it will be described conveniently in this manner and is limited only by the scope of the appended claims.

Referring first to FIGURE 1, there is shown partially an aircraft **10** having wings **12** extending therefrom as viewed from the bottom. This is a convenient illustration although the structure to be described could be disposed within the aircraft or fuselage **10**. In order to obtain vertical or short takeoff lift where normal takeoff in the conventional fashion is not possible, the aircraft may be supplied with lift fans **13**. These are well known and completely described in the aforementioned patent. It is customary to vector the thrust from the gas generator or the lift fans in the illustration to provide for some forward propulsion when transitioning into the horizontal mode. To this end, and to provide lift, the fan may be provided in an opening **14** in the wing surface **12** or any other surface. The opening **14** is designed to pass a fluid therethrough in the well known manner. Movement of the fluid may be either by the conventional lift fan shown or by direct lift engines or by horizontal engines that are exhausted through a duct or any other well known fashion. Suffice to say, that the moving fluid eventually reaches the surface opening **14** and passes through it to impart thrust. Conventionally, it is customary to provide a Venetian-blind cascade of airfoil louvers across the outlet of the opening and, by actuating the louvers, change the direction of thrust of the fluid. With a gas generator disposed above the exit louvers, any throttling due to closing the louvers tends to back pressure the gas generator and, as shown, it back pressures the fan and reduces the fan output. Loss of thrust is the result. Thus, it is necessary that the component above the louver system see at least a minimum decrease in area if it is not to be adversely affected. It should be noted that this also applies wherein the louvers may be used as an inlet system and no throttling is to occur into the device which is intended to use the incoming fluid.

In order to minimize the decrease in exhaust area, the invention proposes to use a swept vane louver system preferably of V-shape as generally indicated in FIGURE 1 employing a cascade of swept airfoil vanes **16** that are conveniently symmetrically swept about a centerline **18**. Each airfoil has its apex **20** disposed on the centerline as shown. For the case of an outlet thrust vectoring system, as seen in FIGURE 2, the apexes are moved away from the surface and directed downstream as shown by arrow **22** which represents the direction of the fluid flow through the outlet louver system.

The term "swept vanes" is a well known term and, for the purposes intended, may be defined as any vane in which the swept surface is one that is not at right angles to the fluid flow direction. Thus, it encompasses a curved surface or a series of straight surfaces which are generally symmetrical about an axis as shown in FIGURE 1 with the apex being the rearward point.

The swept vanes **16** are disposed to lie flat and preferably in overlapping engagement over the surface opening **14** to close the opening in the non-operative position.

In order to obtain vectoring the airfoil vanes of the cascade are movable by any conventional means **26** so that each airfoil is moved or rotated away from the surface. In FIGURE 1, this means that the individual airfoils are rotated downwardly to assume a position as shown in FIGURE 2. It has been found that excellent turning effects at high efficiency are obtained by rotating the individual airfoils a different angular amount from the adjacent airfoils so that, as shown in FIGURE 2, the angle x from the vertical may increase toward the aft direction so that $x<y<z$. As the airfoils **16** are pivoted to a vectored thrust position, the exhaust area decreases. However, since the area in the vertical thrust position is greater than that for straight airfoils, the area reduction in the vectored position relative to the vertical position is less than that for the straight airfoils. Thus, the minimization of the exhaust area decrease enables a greater thrust output from an equivalent sized fan. As the airfoils are rotated by means **26** away from the surface, it will be apparent that triangular shaped areas are uncovered by rotation of the V-shaped airfoils **16** downwardly. This triangular area is shown at **28** in FIGURE 3. Thus, with the swept airfoils **16** it will be apparent that rotation out of the surface opening increases the area by the triangular periphery between the airfoils as at **28** which greater area is uncovered in place of the conventional area **29** between straight airfoils.

It will be seen that the opening **14** as shown in FIGURE 1 is conveniently round in the conventional fashion. This is not necessary and it may be any shape that is convenient for the installation, e.g., rectangular where the vanes are disposed at the end of a rectangular duct as in the outlet in U.S. Patent 3,028,121 and similar installations. With the circular opening, it will be apparent that the span of each airfoil is different from its adjacent airfoil. Thus, as shown in FIGURE 1, airfoil **16** is hinged at **30** and **32** at each end thereof in the opening. The span distance from hinge **30** to hinge **32** in the first airfoil is different from that in the second louver which is longer than its adjacent airfoil.

Normally, centerbody **24** in the straight-vane system represents a blockage. An advantage of the swept vane louver system is that the area occupied by the centerbody **24** is no longer an obstruction when the airfoils are moved away from the surface into the vertical thrust position. The fluid will flow smoothly around the centerbody and make use of the individual airfoils directly under the centerbody since they are moved away from the centerbody. The area of the centerbody is thus added to the flow exit. By maintaining different angles, the flow area decrease of the front portion of the fan is minimized for thrust vectoring while the rear portion of the fan discharge is vectored to a greater extent. The net result is that the overall fan exhaust area is minimized. Additionally, the movement of the airfoils does not open any side passages because of the hinged connections **30** and **32**. In other words, the same effect is obtained by the use of the swept vane louver system as would be obtained by swinging the whole cascade down but without the disadvantages of the mechanical complexities. The disadvantage of the spillage effects around the side of the dropped cascade is avoided since the individual airfoils are connected to the sides of the opening.

The embodiment just described minimizes the reduction in exit or exhaust area for thrust vectoring. Certain modifications will permit the area decrease to be greatly minimized if not eliminated. This is shown in FIGURE 4, where, in addition to the advantages obtained by the swept vane louver system just described, it will be apparent that the sweep angle **34** as well as the airfoil chords may together or individually additionally change from each airfoil to its adjacent airfoil. In this case the individual airfoil louvers **36** may be similarly mounted at their ends in the opening as described in connection with FIGURE 1 and operated in the same manner with the variable angles and chord and the different span length when applied to a circular opening as shown.

In the different sweep angle effect as shown in FIGURE 4, it will be apparent that some airfoils **36** may occur in the circular configuration whereby the depth **39** as shown in FIGURE 5 would be short if the first airfoil were, like the rest, in the dotted position. This defect is overcome by the use of a double hinged airfoil as shown at **42** in FIGURE 5 whereby the depth **40** is increased. With the use of hinge **41**, this provides extra depth or distance **40** for the air to traverse for turning. As shown in FIGURE 5, the different sweep arrangement of the individual louvers may result in a considerably different envelope **43** of the louvers when open. This arrangement minimizes the area decrease by minimizing the reduction in distance between adjacent louvers in the vectored thrust position.

In addition to outlet application, the invention is applicable to inlets. To illustrate, FIGURES 4 and 5 may be thought of as applying to an inlet using the swept louver system wherein the airflow is then shown by the dotted arrow **44**. The airfoil edges would, of course, be compatible with direction of fluid flow. The operation is the same in that each airfoil extends up into the flow and is able to efficiently handle the flow and turn it in to a subsequent downstream surface opening or inlet. In this case, the louvers may be mounted on the upper surface of a wing in the same application. This merely illustrates the versatility of the swept louver system.

In addition to a limited angle of vectoring in the conventional system, there is another limitation in the angle of attack of the entering fluid. In other words, the vanes cannot be turned too far even with the present swept system as so far described, or they begin to stall because the angle of attack gets too high. This merely means that the air strikes the leading edge of the airfoil louvers at too large an angle to permit it to follow the louver surface and separation occurs. This problem may be conveniently handled in the present invention by the use of variable camber airfoils in combination with the swept arrangement. Such variable camber airfoils may be of any suitable construction such as that shown in U.S. Patent 3,172,621. Of course, in an application wherein variable camber airfoils are employed, the swept arrangement generally precludes the variable feature extending the full length of the span of each airfoil. In such an arrangement, as shown in FIGURE 6, a center fixed portion **46** may be provided at the midspan and the variable camber feature may be provided, as in the above patent, on portions **48** connected to the midspan and symmetrically arranged adjacent the midspan. The specific details of the mechanism to vary the camber are not important herein and the small loss that may be encountered in the open position due to the fixed portion **46** is more than offset by the additional advantages obtained by the variable camber portions **48**.

It will be apparent that the swept vane louver system provides for at least a constant area and the use of the normally lost centerbody area for larger turning capabilities than possible in the normal straight vane louver systems. The use of variable sweep angles permits even larger or increased areas. The provision of the means to vary the angles between adjacent louvers merely provides flexibility for higher efficiency. The length of the span of each louver airfoil is dependent on the opening which must be covered resulting in different spans for circular or nonrectangular openings. While not confined to any particular swept vane louver system, the V-shape arrangement as shown in FIGURE 1 where the sweep angle, the chord length, and the camber of all the louvers are constant is preferred for simplicity, efficiency, and ease of manufacture. However, the other modifications shown offer the additional advantages noted.

While there have been described preferred forms of the invention, obvious equivalent variations are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described, and the claims are intended to cover such equivalent variations.

I claim:

1. A vane louver system spanning an annular opening through which a fluid passes said louver system comprising,
   a cascade of airfoils straddling said opening and having pivotally mounted ends,
   each airfoil of the cascade being arched across the the opening for providing a flow path area across the full span of said opening when the airfoils are pivoted to a position permitting flow,
   whereby the reduction in flow area when the airfoils are pivoted to vector the fluid flow is minimized.

2. Apparatus as described in claim **1** having means to vary the camber of each airfoil on symmetrical portions adjacent the midspan.

3. Apparatus as described in claim **1** wherein the airfoils are V-shaped with the apex of the V being movable away from said surface.

4. A thrust vectoring system comprising,
   an annular opening for the discharge of fluid therefrom to produce a thrust,
   a cascade of airfoils, straddling said opening and having pivotally mounted ends,
   each airfoil being arched across the opening for providing a flow path area across the full span of said opening when the airfoils are pivoted to a position wherein flow from said opening is permitted,
   whereby the reduction in flow area when the airfoils are pivoted to vector thrust is minimized,

5. Apparatus as described in claim **1** further comprising:
   means for rotating said airfoils,
   each of said airfoils being rotatable a greater angular distance from a vertical plane than the airfoil on one side thereof,
   whereby the flow area through one side of said opening is increased to provide a maximum fluid flow for a given degree of flow vectoring.

6. Apparatus as described in claim **1** wherein,
   said airfoils are generally V-shaped with the apex of the V being movable away from said opening,
   the chord of each airfoil being greater than the airfoil on one side thereof and the sweep angles of the airfoils varying so that the vanes are pivotable into overlapping closure of said opening.

7. Apparatus as in claim **1** wherein,
   said airfoils are shaped to provide overlapping closure of said opening when positioned generally parallel to said opening.

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