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3,489,339

VANE SEAL

Filed April 16, 1968

2 Sheets-Sheet 1

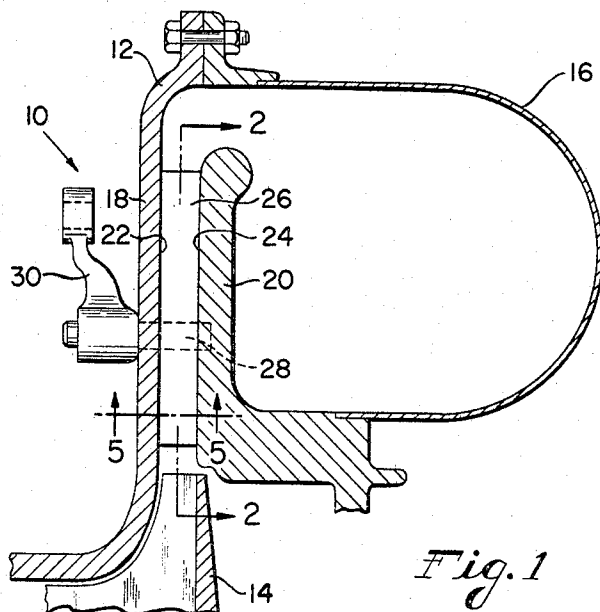


Fig. 1

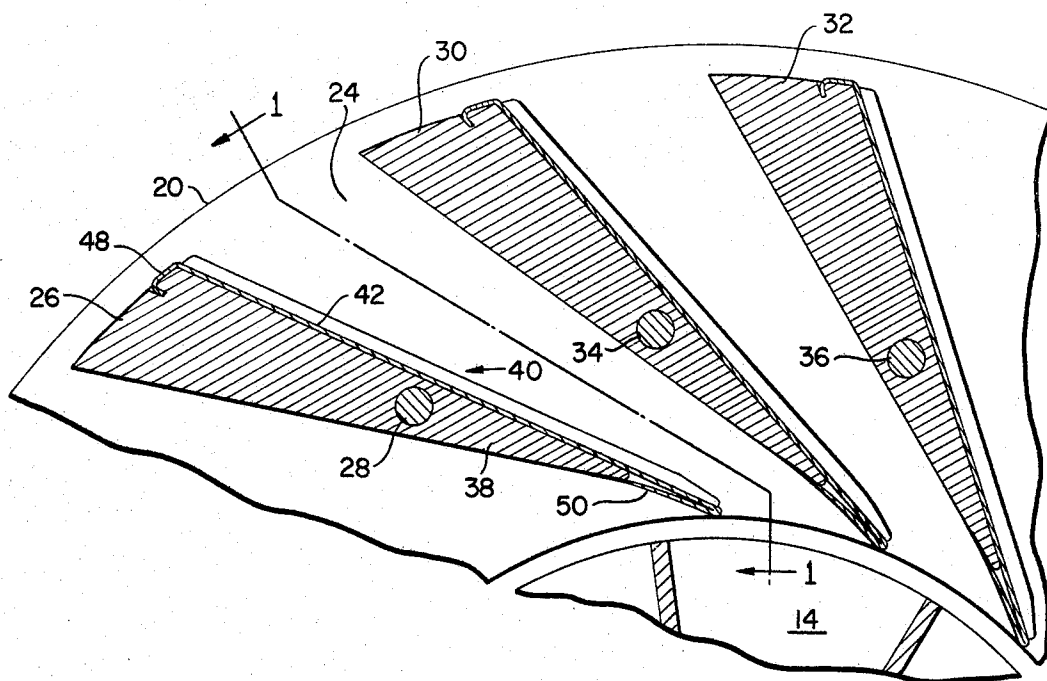


Fig. 2

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2 Sheets-Sheet 2

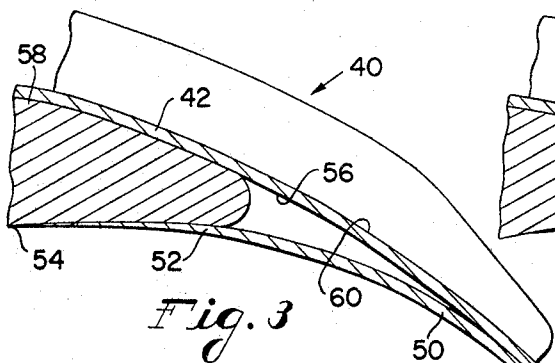


Fig. 3

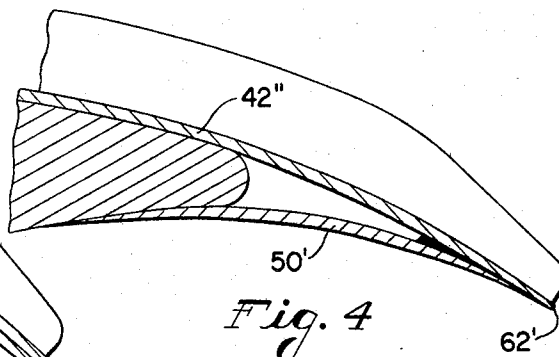


Fig. 4

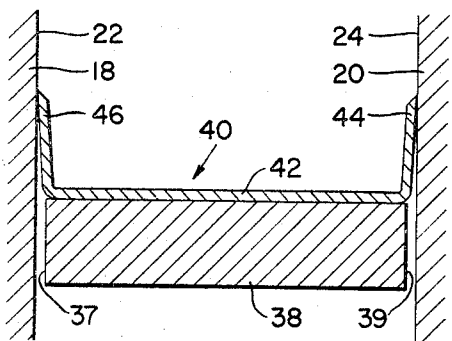


Fig. 5

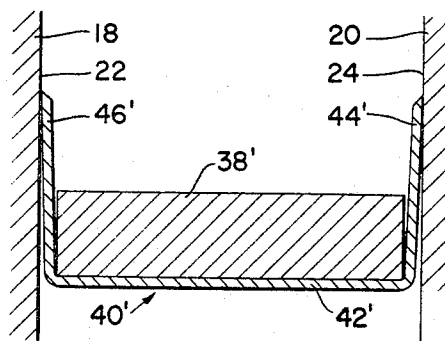


Fig. 6

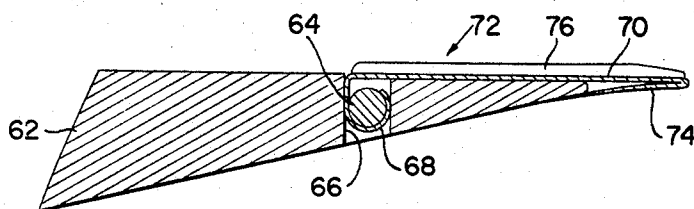


Fig. 7

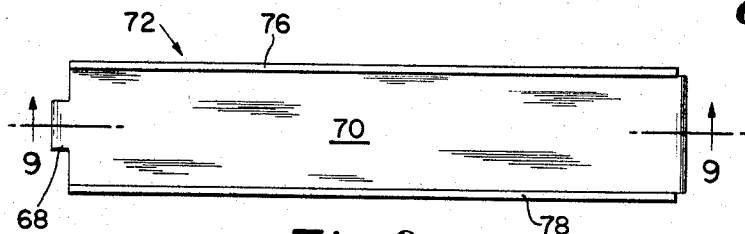


Fig. 8

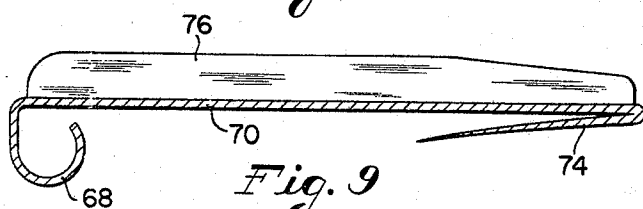


Fig. 9

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VANE SEAL

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19 Claims

ABSTRACT OF THE DISCLOSURE

The movable diffuser vanes of a compressor having a variable diffuser are provided with seal means to prevent leakage between adjacent channels. Each seal has a web-like base portion disposed adjacent one vane surface, with lip seal portions extending from the base portion and bearing resiliently upon the side diffuser walls of the compressor. The extreme upstream tip edge of the base portion forms a sharply edged leading edge for each vane. The upstream and downstream edges of the base portion have elements cooperable with the body structure of the vane to secure the seal means thereto.

BACKGROUND OF THE INVENTION

This invention relates to fluid flow control apparatus generally, and is particularly concerned with the flow controlling variable vanes associated with some fluid rotary machines. More specifically, the invention is concerned with seal means for inhibiting the flow of fluid, along leakage paths normally existing in the clearance space between the side of the vane and the wall adjacent which the vane is movably mounted.

As disclosed herein, the invention will be described in an embodiment employed in combination with the variable diffuser vanes in a supersonic elastic fluid compressor, although it is also applicable to a pump handling liquids.

In the design of elastic fluid rotary compressors having a walled diffuser zone between the compressor wheel discharge and the collector or scroll, it sometimes is required to control the diffusion ratio by means of variable vanes disposed in the diffusion zone and movable with respect to the walls which define the zone. A common practice is to mount the vanes for pivotal movement relative to the adjacent diffuser walls.

It is apparent, of course, that a small clearance space necessarily exists between the walls and the vane sides, and that the clearance space defines leakage paths for the fluid from one fluid control surface of each vane to the other surface thereof, or in other words from one channel to the next channel. As a practical matter, the leakage constitutes no great problem if the leakage is very small, that is of (a) the leakage path is relatively long and narrow and (b) the fluid pressure differential is not great. Also, the leakage can be mitigated to a large extent by precision fabrication of the parts and careful assembly procedures which reduce the clearance space to the barest minimum possible within the operating range of the machine.

However, in the case of a supersonic compressor, for example, the tip portions of the vanes pointing upstream of the fluid flow are sharply edged and very thin in section for quite some distance back from the leading edge. Furthermore, when the vanes are positioned for a relatively high diffusion ratio of more than 11:1, for example, the pressure recovery along the outer or upper surface of a vane begins almost immediately at the leading edge and proceeds rapidly, whereas there is a lesser pressure recovery along the inner or lower surface of the vane until the fluid encounters the throat defined by the

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inner or lower surface of that vane and the upper or outer surface of the immediately next adjacent vane. Hence, a fairly large pressure differential may exist between the upper and lower vane surfaces from the leading edge tip back to at least the vicinity of the throat at the lower surface. In this case, leakage occurring past the side edge portions of the vanes and most particularly at or near the leading edge tips thereof may degrade compressor performance seriously.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the inadequacies of the prior art by providing seal means for a vane which will serve to inhibit fluid flow through leakage paths existing between the sides of said vane and adjacent diffuser walls or from one fluid flow direction face surface of said vane to the other. The object is accomplished by a seal structure comprising a lip type seal portion extending from said vane, in resilient contact with the wall adjacent the vane edge. Desirably, the lip seal portion forms an angularly disposed extension of a web-like base portion of the seal structure, a face surface of the base portion being disposed immediately adjacent a face surface of the vane body structure.

In a supersonic compressor, the leading edge tips of the vanes may be required to have a relatively sharp or knife edge character. It is an object of the invention to form the leading edge tips of the vanes from the most upstream nose or tip of the web-like base portions of the seal structures. Preferably, the seal structure is formed with a substantially U-shaped or channeled configuration in a transverse cross section which is normal to the fluid flow, with lip seal portions extending upwardly from the base portion which has one face surface disposed immediately adjacent one of the face surfaces of the vane body.

Preferably, also, the seal structure may be formed or stamped from strip metal material, for example. The seal structure may be provided with resilient, longitudinally disposed strip extensions of the base portion which enable the seal structure to be secured to the vane body. Such a structure is relatively simple to manufacture, is economical and costs very little for replacement at overhaul time, for example, when wear at the lip seals or erosion at the leading tip edge calls for such replacement. This is much cheaper than replacement of the entire vane means which may be a relatively complicated and costly structure to fabricate.

The invention has, thus, generally objects to provide a seal for a variable fluid flow control vane having a sharp leading edge which will be inexpensive to fabricate and to maintain and at the same time introduce no complexities or added cost factors to the original design, fabrication and assembly of the apparatus employing the vane.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation view showing an axial section of a portion of an elastic fluid compressor, taken on the line 1—1 of FIG. 2;

FIG. 2 is an elevation view showing a transverse cross section of a portion of the compressor of FIG. 1, taken on the line 2—2 thereon;

FIG. 3 is an enlarged cross section view of the tip portion of one of the vanes of FIG. 2 and its vane seal;

FIG. 4 illustrate an alternate embodiment of the seal of FIG. 3;

FIG. 5 is an enlarged cross section view of the vane and vane seal, taken generally on the line 5—5 of FIG. 1;

FIG. 6 is a view similar to FIG. 5, showing an alternate embodiment of a vane seal;

FIG. 7 is a cross section view of a single vane similar

to one of those of FIG. 2 and showing an alternate embodiment of a vane seal;

FIG. 8 is an enlarged plan view of the seal of FIG. 7; and

FIG. 9 is an elevation cross section view of the seal of FIG. 8, taken on the line 9—9 thereon.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown a portion of an elastic fluid compressor 10 comprised of a stator structure 12 and a rotor having a compressor wheel shown fragmentarily at 14. The stator 12 includes a collector or scroll 16 for the elastic fluid compressed by the wheel 14 which discharges into a diffuser zone defined by the walls 18 and 20 of the stator 12. Means not pertinent to the invention, hence not shown, are provided to conduct the compressed gas from the collector 16 to the point of use.

The stator walls 18 and 20 provide parallel face surfaces 22 and 24 between which are disposed a plurality of variable vane means to control the flow of fluid in the diffuser zone. One of the vane means is shown at 26 secured to a pivot shaft 28 so as to pivot therewith in accordance with rotary adjustment imparted thereto by means of a crank 30, for example, or by any other preferred means as will be well understood by those skilled in the art.

As thus far described, the compressor 10 is quite conventional, being shown in FIG. 1 in more or less schematic form to provide the setting and the basis for the novel vane seal now to be described. As noted above, the compressor diffuser includes a plurality of vane means. Referring now to FIG. 2, there is shown vane means 26, 30 and 32 which, in the embodiment shown, comprise three of a total of 15 vane means employed in the example compressor illustrated and equally distributed around the axis thereof. Vane means 30 and 32 are pivotally secured on pivot shafts 34 and 36, respectively, so as to be pivotally movable counterclockwise, in unison with vane means 26 relative to the surface 24 of the wall 20. In the embodiment shown, the vane means may pivot through an angle of about 22°, and the diffusion ratio may thus vary from about 2.20:1 to about 11.90:1 as the vane means move from one extreme position to the other.

Considering specifically the vane means 26, this means will be seen as comprising a vane body 38 and a seal means 40. As best seen in FIG. 5, the seal means 40 comprises a base portion 42 and lip seal portions 44 and 46 extending upwardly toward the higher pressure channel from the base portion 42, said seal portions having resilient sealing contact with the wall surfaces 24 and 22 respectively, to inhibit or minimize the leakage flow of fluid from the vicinity of one surface of the vane means 26 to the other surface through the paths between the wall surfaces and the side walls 37 and 39 of the body 38. Thus if, for example, a fluid pressure of the top surface of the vane means should exceed the pressure of the bottom surface, the lip seals would tend to inhibit leakage flow by reason of the pressure differential existing between the surfaces.

It will be apparent that the vane body 38 and seal means 40 may be slightly altered in configuration, to permit the seal means to underlie the vane body rather than to overlie it as shown in FIG. 5. An embodiment of this type is illustrated in FIG. 6 wherein the seal means 40' has a base portion 42' which underlies the vane body 38', and to this end the body 38' is fabricated to a lesser width to permit accommodation of the lip seal portions 44' and 46' between the body 38' and the walls 20 and 18, respectively. This arrangement provides longer and more flexible sealing lips for a given thickness of the resilient material from which the vane sealing means is fabricated.

Referring back to FIG. 2, it will be seen that the vane means 40 may be secured to the vane body 38 by a heel clip portion 48 and a tip or nose clip portion 50. Both of the clip portions 48 and 50 may be formed as longitudinal extensions of the base portion 42, both being reversely directed longitudinally as shown in FIG. 2, to provide the clip securing function for the vane means 40. As seen in FIG. 2, the heel clip portion 48 is received within a groove formed in the heel of the vane body 38. The formation of the nose clip portion 50 is best seen in the enlarged version illustrated in FIG. 3, the trailing tail end 52 of the nose clip portion 50 being thinned and feathered to fair into the under surface 54 of the vane body 38.

The clip arrangement as aforesaid illustrates the securing of the vane means 40 to the vane body 38 with the under surface 56 of the base portion 42 in intimate contact with the upper surface 58 of the body 38 throughout the length of the body with the upper surface 60 of the base portion 42 of the seal means 40 providing a fluid flow directing surface and channel cooperatively with the adjacent vane's under surface 54 of the vane body 38.

In cases where it is desirable to have a vane with a leading edge that is sharper than the nose 62 provided by reversely directing an extension of the base portion 42 to form the nose clip 50, the arrangement can take the form illustrated in FIG. 4. Therein, a tip or nose portion 62' of the base portion 42' is chamfered on the under side thereof, whereafter the nose clip portion 50' may be brazed or welded, for example, or otherwise secured thereto. An advantage of this construction is that the clip portion 50' may be fabricated from a thinner or a different metal material than that from which the seal means is fabricated.

As was pointed out hereinabove, the leakage across the side edges of the vanes is dependent upon vane side clearances and upon the pressure differential between the upper and lower vane surfaces and upon the length of the leakage paths between the side edges of the vanes and the diffuser walls. From the configuration of the vanes, it is apparent that the leakage path lengthens as the downstream distance from the tip of the vane increases. Furthermore, the pressure differential across the vane tends to decrease with increased downstream distance from the vane tip. Accordingly, in certain cases it may be desirable or even advantageous to provide a seal means for the vane in which the lip seal portions do not extend downstream along the vane for substantially its whole length. A vane and seal structural arrangement for this purpose is illustrated in FIGS. 7, 8 and 9.

Referring to FIG. 7, there is shown a vane body 62 pivotally mounted for rotation with the pivotal shaft 64 about its axis. The body 62 is provided with a slot 66 which is adapted to receive and accommodate the curled heel portion 68 formed on the extreme downstream end of the base portion 70 of the seal means 72. Preferably, the width of the heel portion 68 is approximately one-third the width of the base portion 70 as best seen in FIG. 8. In such case, the slot 66 in the vane body 62 would extend in width only about one-third the width of the vane body, hence would not represent any undue weakening of the body to accommodate the structure itself. It is apparent, of course, that other forms of means to clip the rear or downstream end of the vane means 72 to the vane body 62 could be readily devised by those skilled in the art. The form shown in FIGS. 7, 8 and 9 is intended to be merely exemplary of the ultimate desired structure, which may also be provided with a nose clip portion 74 at the forward or upstream portion of the base portion 70 to secure that end of the seal means to the vane body. It is considered obvious to form the base and nose portions 70 and 74 after the manner shown in either FIG. 3 or FIG. 4.

It is also obvious that, in lieu of the heel and tip or nose portions seen in the various figures, the seal means

may be secured by brazing the base portion of the seal means to the surface of the vane body.

It will be observed in FIG. 8, that the seal means 72 comprise lip seal portions 76 and 78 extending from the base portion 70. The lip seal portion 76 and 78 are arranged to be in resiliently sealing contact with the compressor diffuser walls in the same manner as the lip seal portions 44 and 46 of FIG. 5.

As best seen in FIG. 7, the lip seal portion 76 extends longitudinally of the van body 62 from the upstream tip to approximately one-half way toward the rearward heel of the downstream end of the vane body 62. Thus, the lip seal provides inhibitory action with respect to leakage at the most critical portion of the van body, to wit the tip or nose end portions where the leakage paths across the edges of the vane body are the shortest and the pressure differential is the greatest.

What is claimed is:

1. Fluid flow control apparatus comprising:

- (a) a fixed wall defining a fluid flow zone;
- (b) vane means having a pair of surfaces for directing fluid flow in channels adjacent said surfaces and having a side wall portion;
- (c) means mounting said vane means for movement in said zone with said side wall portion of said vane means adjacent said fixed wall, the clearance space between said side wall portion and said fixed wall establishing a leakage path from one of said channels to the other; and
- (d) seal means disposed on said vane means and movable therewith relative to said fixed wall, said seal means comprising a resilient lip seal portion disposed at an acute angle with said fixed wall and engaged in resilient sealing contact therewith, thereby serving to minimize fluid flow through said leakage path between said channels.

2. The apparatus of claim 1 in which:

said vane means is mounted for pivotal movement relative to said fixed wall.

3. The apparatus of claim 1 in which:

said seal means includes a web-like base portion having one face surface disposed immediately adjacent a face surface of said vane means, the other face surface of said base portion serving at least in part as one of said pair of surfaces of said vane means, said lip seal portion being an angularly disposed extension of said base portion.

4. The apparatus of claim 3 in which:

a tip end of said base portion is disposed as a leading edge for said vane means within said fluid flow.

5. In a fluid flow machine:

- (a) a pair of fixed walls defining a fluid flow zone;
- (b) vane means having a pair of surfaces for directing fluid flow, and having side wall portions;
- (c) means mounting said vane means for movement in said zone with said side wall portions of said vane means adjacent said fixed walls, the clearance space between said side wall portions and said fixed walls establishing leakage paths from one of said surfaces to the other; and
- (d) seal means disposed on said vane means and movable therewith relative to said fixed walls, said seal means comprising a web-like base portion and a pair of lip seal portions extending from said base portion and in resilient sealing contact with said fixed walls and thereby serving to minimize fluid flow through said leakage paths.

6. The machine of claim 5 in which:

said base and lip seal portions of said seal means are generally U-shaped in cross section normal to said fluid flow,

said base portion having a sharply edged leading edge extending in an upstream direction of said fluid flow, said leading edge serving to divide said fluid flow into two portions to flow over said

surfaces of said vane means at different fluid pressures.

7. The machine of claim 6 in which:

said walls are substantially parallel and said vane means is mounted for pivotal movement relative to said walls.

8. The machine of claim 5 in which:

said web-like base portion of said seal means is disposed immediately adjacent one of said surfaces of said vane means, securing means being provided for securing said seal means to said vane means.

9. The machine of claim 8 in which:

said securing means comprises a longitudinal extension of said base portion.

10. The machine of claim 9 in which:

said base portion comprises a tip edge extending in an upstream direction of said fluid flow; and said base portion extension comprises a resilient web-like portion extending downstream from said tip edge and angularly disposed with respect to said base portion so as to be resiliently engaged over a nose portion of said vane means.

11. In an elastic fluid compressor;

- (a) fixed walls defining a diffuser zone;
- (b) vane means having a pair of surfaces for directing fluid flow and having side wall portions;
- (c) means mounting said vane means for movement in said zone with said side wall portions of said vane means adjacent said fixed walls, the clearance space between said side wall portions and said fixed walls establishing a leakage path from one of said surfaces to the other; and
- (d) seal means disposed on said vane means and movable therewith relative to said fixed walls, said seal means comprising resilient lip seal portions disposed at acute angles with said fixed walls and engaged in resilient sealing contact therewith, thereby serving to inhibit fluid flow through said leakage path.

12. The compressor of claim 11 in which:

said fixed walls are substantially parallel and said vane means is mounted for pivotal movement relative thereto.

13. A fluid flow control vane having upper and lower surfaces defining fluid flow channels for fluids of differing pressures over at least a portion of said surfaces, said vane having sidewalls and being arranged for adjustably moving disposition within a zone of fluid flow between a pair of fixed walls with the side walls of said vane adjacent said fixed walls, and with the clearance therebetween providing fluid leakage paths form the channel of higher to the channel of lower pressure,

said vane having a tip comprising a sharply edged leading edge portion facing upstream of the direction of fluid flow, and having lip seal portion extending angularly from said leading edge portion toward the channel of higher pressure,

said lip seal portion having a springy characteristic adapted to urge said lip seal portions into resilient contact with said fixed walls when said vane is installed therebetween,

said lip seal portions having a length extending from substantially the extreme upstream sharp edge of said tip for a necessary distance in the direction of fluid flow in said channel of higher pressure to minimize fluid leakage from channel to channel.

14. The vane of claim 13 in which:

said vane is pivotally movable with respect to said fixed walls.

15. The vane of claim 14 whose side walls are substantially parallel for disposing the vane between a pair of substantially parallel fixed walls.

16. The vane of claim 13 in which:

said vane is comprised of a vane body and seal means,

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said seal means being comprised of a base portion and said lip seal portions, said leading edge portion forming an upstream extension of said base portion.

17. The vane of claim 16 in which: said base portion forms the upper surface defining the channel of higher pressure of said vane.

18. The vane of claim 16 in which: said base portion forms the lower surface defining the channel of lower pressure of said vane, and said lip seal portions extend upwardly from said base portion intermediate said side walls and said fixed walls.

19. The vane of claim 15 in which:

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said upper and lower surfaces are normal to said side walls.

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