United States Patent [19]

O'Connor

[11] **3,768,919**

[45] **Oct. 30, 1973**

[54] **PIPE DIFFUSER WITH AERODYNAMICALLY VARIABLE THROAT AREA**

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[21] Appl. No.: **190,199**

[52] **U.S. Cl.** **415/116,** 415/151, 415/DIG. 1

[51] **Int. Cl.** **F04d 29/44,** F04d 27/02

[58] **Field of Search** 415/DIG. 1, 207, 415/98, 151, 116

[56] **References Cited**

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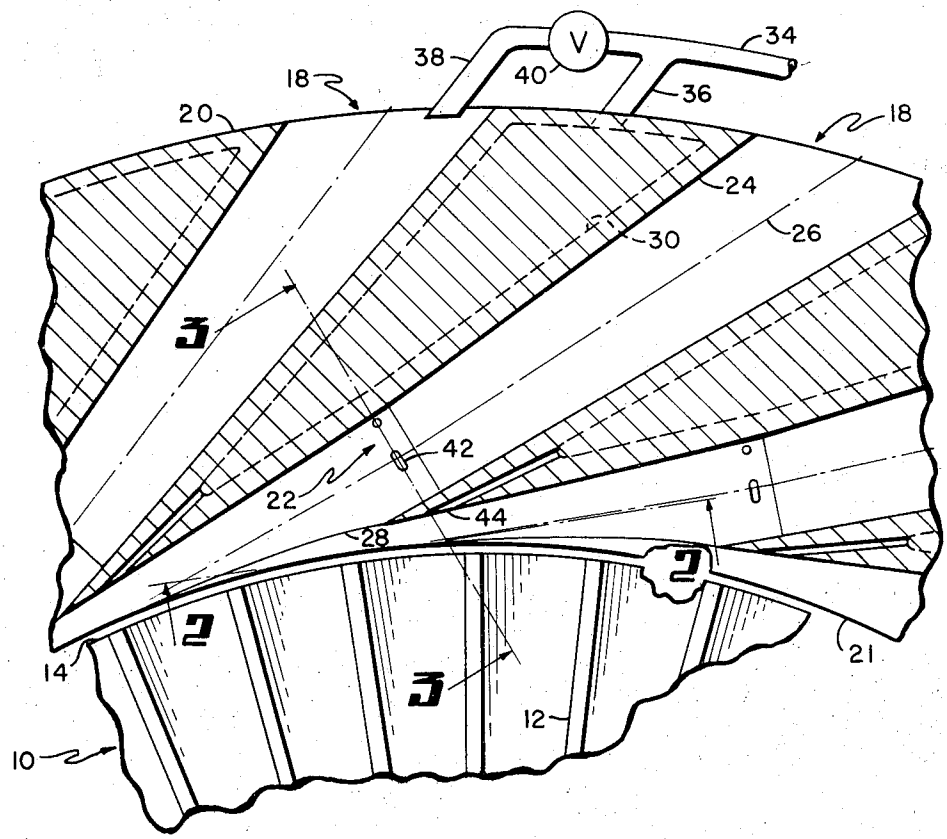
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[57] **ABSTRACT**

A "pipe" diffuser comprises an annular housing surrounding a centrifugal impeller and has primary diffuser passages intersecting with one another to form scallop-shaped entrance edges. A series of ports are provided in the throat region of the diffuser passages to momentarily inject pressurized diffuser exit air to aerodynamically vary the throat flow characteristics and prevent surge during operation of the stage above its normal surge line.

8 Claims, 5 Drawing Figures



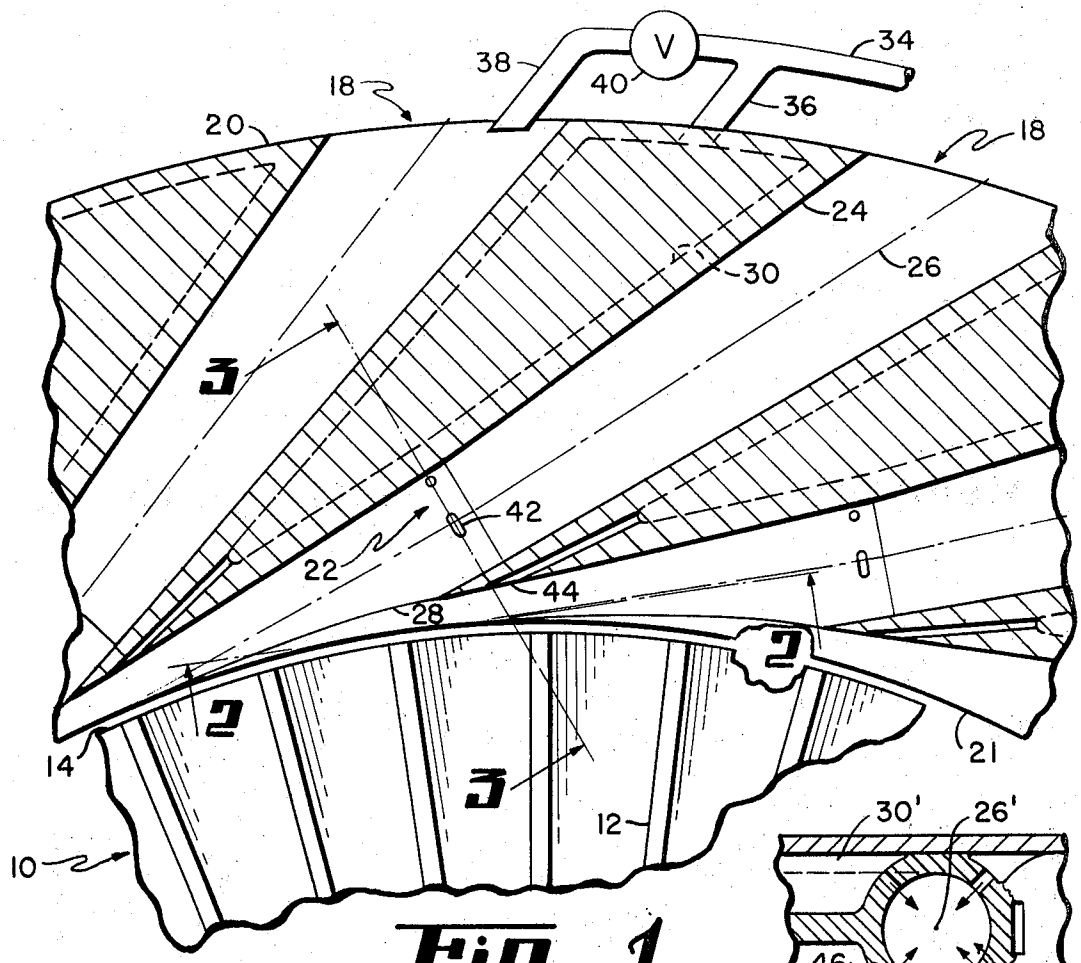


Fig 1

Fig 4

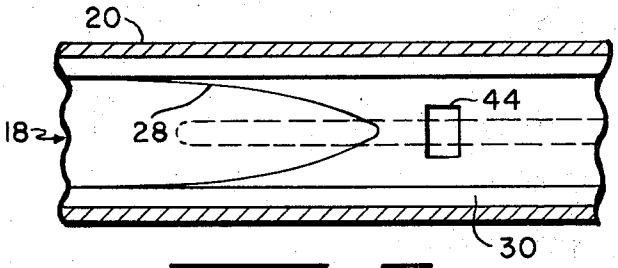


Fig 2

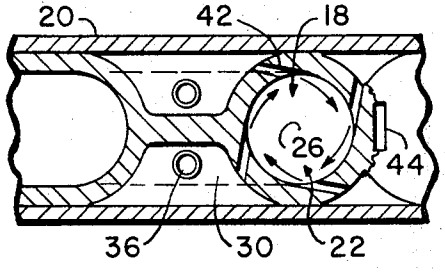


Fig 3

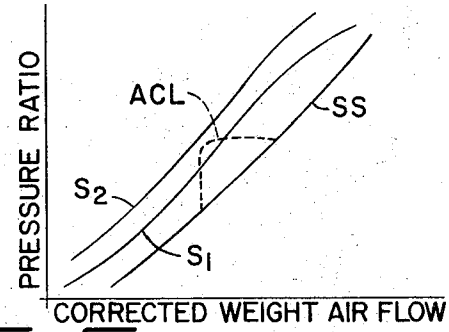


Fig 5

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PIPE DIFFUSER WITH AERODYNAMICALLY VARIABLE THROAT AREA

This invention was made under a contract with the U. S. Government.

The present invention relates to compressor assemblies and more particularly to compressor assemblies utilizing the "pipe" diffuser.

The so-called "pipe" diffuser has been used in centrifugal compressors to achieve high pressure ratios. This type of diffuser is illustrated in U. S. Pat. No. 3,333,762 in the name of J. C. Vrana. This diffuser generally comprises a series of tangentially extending conical passages in a housing which surrounds the periphery of a centrifugal impeller. The passages intersect adjacent the periphery of the impeller in such a fashion that they produce scallop-shaped inlet edges for the diffuser passages. The scalloped edges conform more closely to the velocity distribution of the air leaving the impeller to produce a highly efficient handling of both subsonic and supersonic flows discharged from the impeller.

Normally in a compressor of the above type as utilized in a gas turbine engine, it is designed to operate as closely as possible to the compressor surge line in order to provide the most efficient compressor performance. This operating line is a steady state operating line, however, and when the engine is accelerated to a higher rotational speed the operating point of the compressor stage tends to move toward and across the surge line. The resultant instability and back flow produces a great loss in efficiency and performance. For prior art vane-type diffusers surge during acceleration has been avoided by mechanically altering the configuration of the diffuser. In the pipe diffuser, however, a mechanical alteration is difficult, if not impossible due to the complex sealing and component displacing problems. At present the only alternative for a pipe diffuser is to provide an operating line sufficiently removed from the surge line so that acceleration will not cause the compressor to go into surge.

Therefore it is an object of the present invention to provide a compressor with a pipe diffuser of the above general type that operates at a high level of efficiency closely adjacent the surge line for both steady state and transient conditions without going into surge.

This end is accomplished by incorporating in a pipe diffuser means for injecting air into the throats of the pipe diffuser passages to aerodynamically alter the flow characteristics of the diffuser. This change in the diffuser characteristic allows a controlled surge line shift for the stage which can be utilized to prevent surging during transient operation when the surge line would normally be exceeded.

The above and other related objects and features of the present invention will be apparent from a reading of the description of the disclosure shown in the accompanying drawing and the novelty thereof pointed out in the appended claims.

In the drawing:

FIG. 1 is a sectional view of a centrifugal compressor incorporating a diffuser which embodies the present invention;

FIGS. 2 and 3 are fragmentary sectional views of the diffuser of FIG. 1 taken on lines 2—2 and 3—3, respectively, of FIG. 1;

FIG. 4 is an alternate embodiment of the diffuser shown in FIG. 1; and

FIG. 5 is a graph of pressure ratio versus corrected weight air flow for the compressor assembly of FIG. 1.

Referring to FIG. 1 there is shown a rotatable centrifugal impeller 10 having blades 12 which pressurize and accelerate air for discharge through an annular region defined generally by the periphery 14 of the impeller 10. The air thus discharged enters into a series of diffuser passages, generally indicated by reference character 18, formed in an annular diffuser housing 20. Housing 20 has an inner diameter 21 surrounding the periphery 14 of impeller 10. As herein shown, each of the passages 18 comprise a generally constant cross-sectional area throat portion 22 and a conical outlet portion 24. The longitudinal axes 26 of each passage 18 are positioned so that the throat portions 22 intersect with adjacent throats to produce a series of scallop-shaped inlet edges 28, as seen particularly in FIG. 2.

As shown in FIG. 3, the diffuser housing 20 has a series of chambers 30 in between adjacent diffuser passages 18 around the periphery of housing 20. Each chamber 30 is connected to a suitable air distribution system comprising a manifold conduit 34 and connecting conduits 36 (only one of which is shown) leading from the manifold conduit 34 to the chambers 30. Manifold conduit 34 is connected to the outlet of the diffuser passages 18 by means of a suitable connection system illustrated in simplified form as a conduit 38 by way of a control valve 40. It should be apparent to those skilled in the art that other forms of air distribution systems may be used to supply pressurized diffuser exit air to the regions adjacent each throat 22 of the diffuser passages 18.

A series of ports 42 connect chambers 30 with the throat 22 of the passages 18. As illustrated in FIG. 3 ports 42 extend tangentially relative to the longitudinal axis 26 of the passages 18. An additional passageway 44 connects the chamber 30 with the low pressure side of scalloped leading edges 28, as will be described below in detail. The passage 44 is in the form of an elongated slot. As is apparent, passage 44 may be supplied with air from a different distribution system at different pressure levels if desired.

During steady state operation the compressor operates along the operating line SS shown in FIG. 5. This line SS generally conforms to and is closely adjacent to surge line S_1. During acceleration or certain other transient operation of the engine, the operating line temporarily follows the line ACL which would place the diffuser above the surge line S_1. However, during this transient condition the valve 40 is opened to permit the flow of air from the diffuser outlet to the throats 22 which are at a lower static pressure level. The ports 42 inject the air into the stream which aerodynamically reduces the flow area of the throat, thus moving the surge line to line S_2 which is well away from the transient operating line ACL. When the steady state condition has again been reached the valve 40 is closed, thus terminating the flow. The pressure in chambers 30 and throats 22 are now equalized and there is no net flow into the chambers.

The use of the slotlike passage 44 may be used in addition to or separately from the ports 42 to aerodynamically change the flow characteristics of the scalloped leading edges 28. Injection of air through passage 44 changes the flow characteristics in the following manner. In the absence of flow passages, air discharged from the periphery of impeller 10 tends to follow along

a free vortex flow path. The diffuser passages **18** tend to divert the air more radially outward than a path following the laws of free vortex motion. As a result, the radially outboard side of scalloped edge **28** tends to have a pressure higher than the radially inboard side of edge **28.** The injection of air through slot **44** to the low pressure side tends to make a blunter leading edge and aerodynamically produces an optimum angle of incidence for the scalloped edge **28** that is more tangential. The injection of air from slot **44** injects air into the separation region which forms under the high positive incidence conditions existing and delays stalling around the scalloped leading edge **28.**

FIG. **4** shows a different embodiment for injecting air into the throats of the diffusers. In this figure there are shown ports **46** extending from chambers **30'** into the throats **22'** of the diffuser passages **18'**. It will be noted that ports **46** are directed radially inward with respect to the longitudinal axis **26'** of the diffuser passages **18'**. Injection of air through these ports aerodynamically reduces the throat area in a fashion similar to that for ports **42** shown in FIGS. **1, 2** and **3.** By varying the injection angle we are able to produce a variation in blockage for a fixed flow rate. It should be apparent that the ports **46** may even be angled forward or aft or varied in size to produce a variation in blockage for a given injected air flow.

The diffuser systems described allow a compressor assembly to be matched as close as desired to the surge line for steady state operation to attain a maximum efficiency, yet have a sufficient surge margin for transient operation. A momentary decrease in efficiency occurs during acceleration due to the pressure losses of recirculating the compressor discharge air and deterioration of diffuser performance due to blockage. However, because of the short time these conditions are incurred they will not significantly effect the overall engine mission performance.

In each of the arrangements described above the precise degree of flow blockage may be adjusted to given compressor performance criteria by selecting the size and number of the holes, as is apparent to those skilled in the art. These arrangements permit a diffuser with a high degree of efficiency in addition to a substantial surge margin for both steady state and transient operating conditions.

While the preferred embodiment of the present invention has been described, it should be apparent to those skilled in the art that further modifications may be performed without departing from the spirit and scope.

Having thus described the invention, what is claimed as novel and desired to be secured by Letters Patent of the United States is:

1. A compressor assembly comprising:

a rotatable bladed impeller having an annular discharge region;

an annular diffuser housing surrounding the discharge of said impeller, said diffuser having a plurality of generally conically diverging tangentially directed diffuser passages having throats which intersect adjacent the discharge of said impeller to form a series of generally scalloped inlet edges to said diffuser passage throats, said diffuser passages having an angle of incidence with respect to the air leaving the discharge region of said impeller that directs the air more radially outward than a free vortex flow, thereby creating high and low pressure regions on opposite sides of said scalloped inlet edges; and

means for injecting air into the throats of said diffuser passages and means for supplying a source of air adjacent said throats at a static pressure level higher than that of the air in the throats of said passages, and means for forming ports from said source of pressurized air for injection into the throats of said diffuser passages to aerodynamically alter the flow characteristics of said throats and means including ports for injecting air to the low pressure side of said scalloped inlet edges thereby aerodynamically reducing the effective incidence of the passages relative to the flow from the impeller.

2. A compressor assembly as in claim **1** wherein said port is a slot for injecting a sheet of air generally over the low pressure side of said scalloped inlet edge.

3. A compressor assembly as in claim **1** wherein said injection port means includes ports directing air generally tangentially with respect to the longitudinal axis of said throats to aerodynamically reduce the cross-sectional flow area thereof.

4. A compressor assembly as in claim **1** wherein said injection port means includes ports positioned to direct air radially inward toward the longitudinal axis of said throats to aerodynamically reduce the cross-sectional flow area thereof.

5. A compressor assembly as in claim **1** wherein said air supply means comprises:

means for extracting pressurized air from the discharge of said diffuser passages; and

means for distributing said air to a point adjacent the throats of said passages.

6. A compressor assembly as in claim **5** wherein said distributing means comprises a series of chambers formed in said diffuser housing in between adjacent diffuser passages and conduit means connecting the discharge from said diffuser passages to said chambers.

7. A compressor assembly as in claim **5** wherein said injection port means additionally define ports directed tangentially with respect to the longitudinal axis of said throats to aerodynamically reduce the cross-sectional flow area thereof.

8. A compressor assembly as in claim **5** wherein said injection port means additionally define directing air radially inward with respect to the longitudinal axis of said throats to aerodynamically reduce the cross-sectional flow area thereof.

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