

[54] **SURGE CONTROL FOR FLUID COMPRESSORS**

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FOREIGN PATENTS OR APPLICATIONS

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[57] **ABSTRACT**

[52] U.S. Cl..... **415/52, 415/11, 415/27,**
415/147, 415/DIG. 1

[51] Int. Cl..... **F01d 1/12**

[58] Field of Search **415/11, 27, 28, 45,**
415/52, 147, DIG. 1

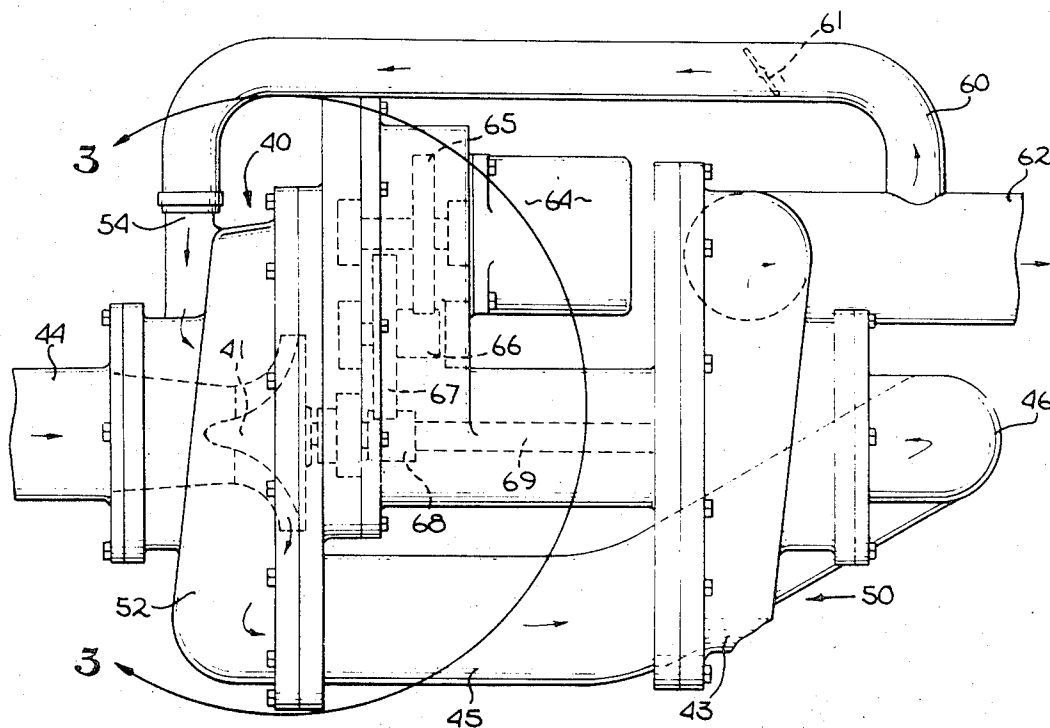
A control means for preventing surging under changing or low flow conditions in a fluid compressor such as an air compressor which includes a rotor and diffuser and at least two stages of compression is disclosed. Compressed air from the $n+1$ stage of the compressor is injected into the diffuser of the n th or lower stage of the compressor through a collection chamber which is disposed about the diffuser.

[56] **References Cited**

UNITED STATES PATENTS

2,660,366 11/1953 Klein et al. 415/DIG. 1

9 Claims, 4 Drawing Figures



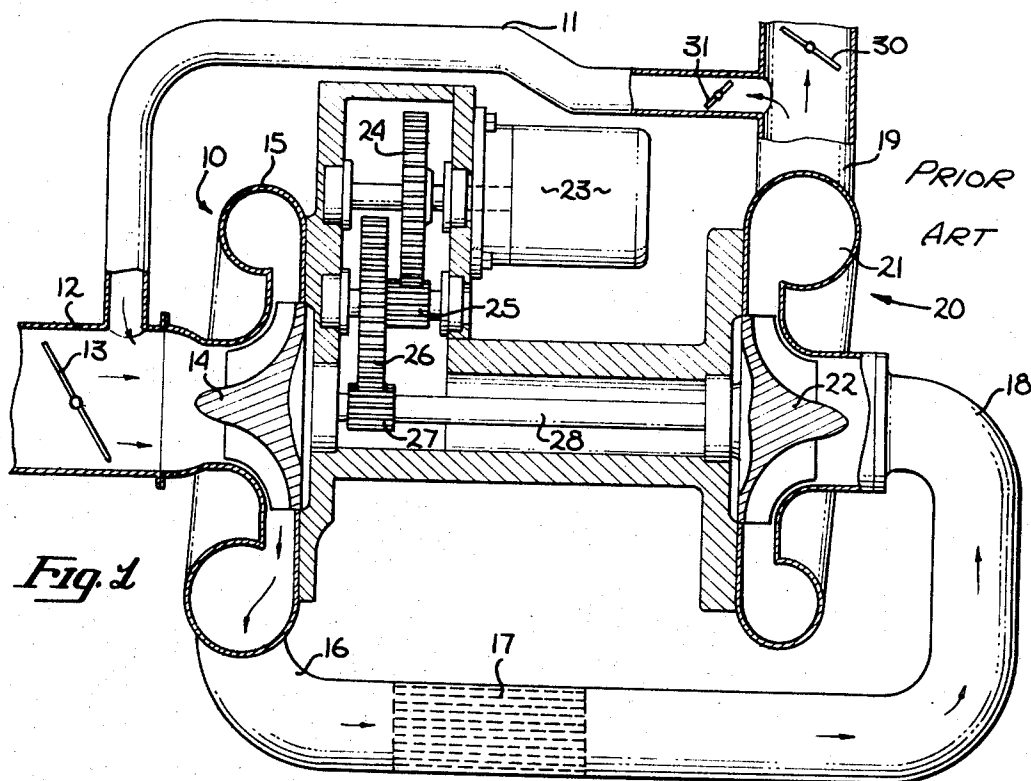


Fig. 1

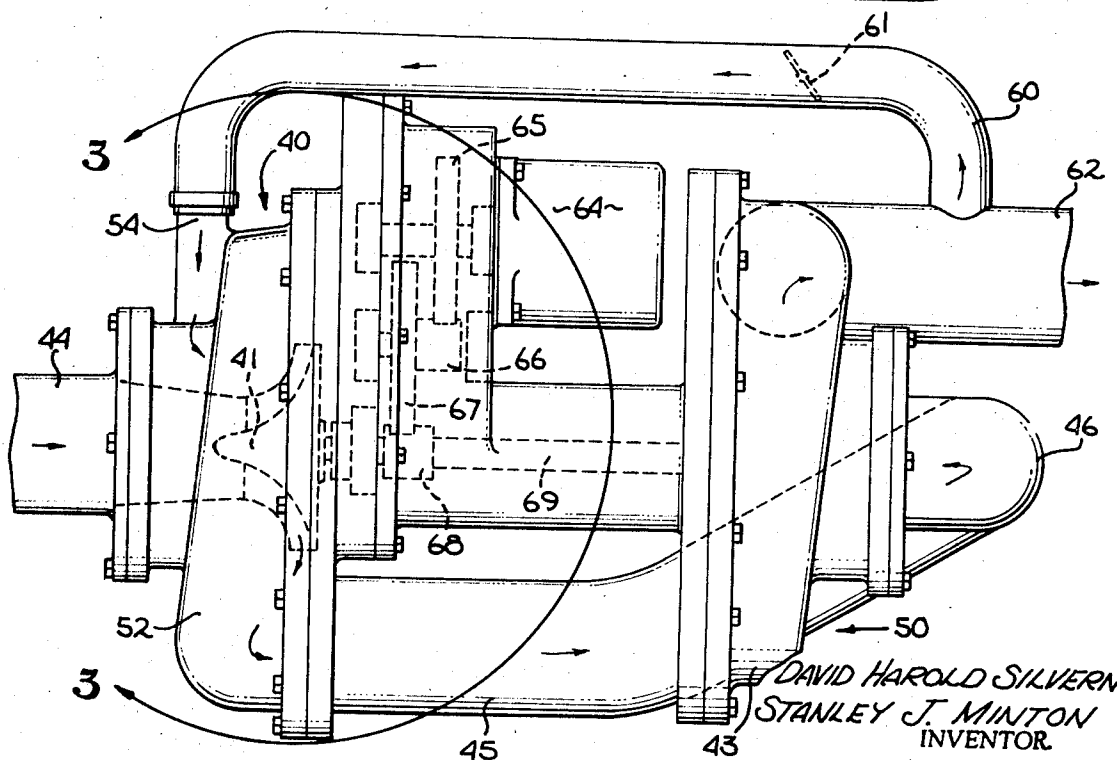


Fig. 2

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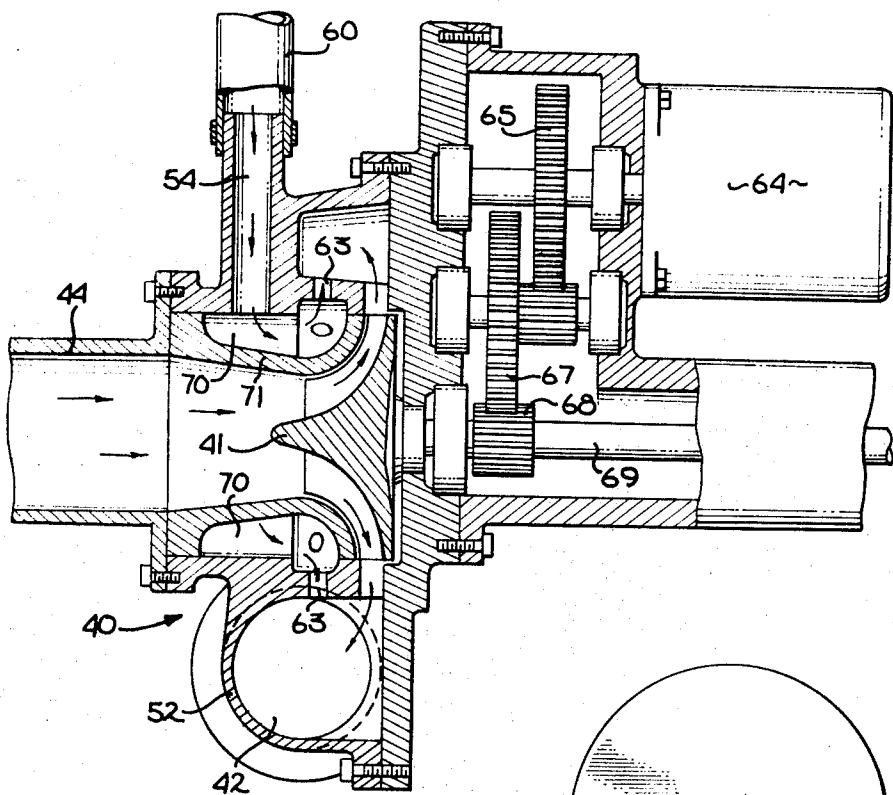


Fig. 3

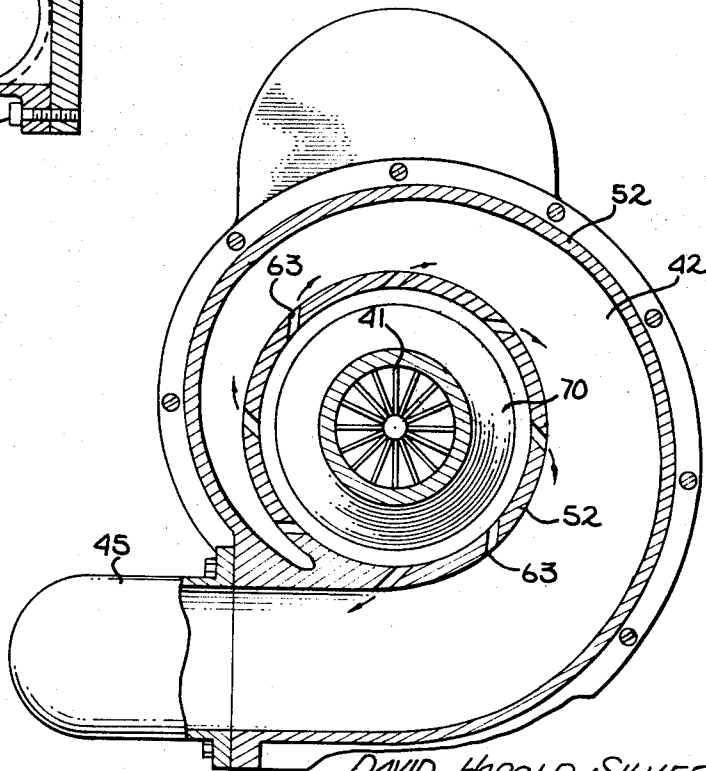


Fig. 4

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SURGE CONTROL FOR FLUID COMPRESSORS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to means for controlling surging in centrifugal compressors.

2. Prior Art

Centrifugal compressors which utilize rotors and diffusers to compress fluids such as air are well known in the art. While these devices are efficient for a constant predetermined flow they exhibit undesirable characteristics such as surging when the flow drops below the predetermined level. For example, in some centrifugal compressors surging occurs when the flow through the compressor drops below 80 percent of the compressor's predetermined or optimum flow. The surging results from the building up and breaking down of various boundaries and layers of fluid within the compressor. The surging is an undesirable characteristic since it results in an uneven flow of air from the compressor.

Numerous attempts have been made in the prior art to control surging. One method for controlling surging is to permit the compressor to operate at its predetermined or optimum flow level independently of the demand for fluid from the compressor. This is generally accomplished by discharging the high pressure fluid at the outlet of the compressor when the fluid is not being used. An obvious disadvantage to this method is the fact that the work performed on the fluid in compressing it is wasted when the high pressure fluid is discharged.

Another method for controlling surging is that described in U.S. Letters Patent No. 2,660,366. In this patent compressed fluid such as air is recirculated through the compressor by injecting it into the stream of air before that stream contacts the compressor rotor.

It appears from a review of the prior art techniques for preventing surging that the principal efforts have been directed towards preventing surging caused by the compressor rotor. Tests have indicated that in many centrifugal compressors the rotor is more tolerable of low flow conditions than is the diffuser. For example, in some instances it has been found that a reduction of flow of about 20 percent will cause surging in a compressor and that the cause of surging was attributable to the flow of air in the diffuser and not the flow of air in the rotor. On the same compressor it was found that a decrease of flow of about 60 percent was required before surging problems attributable to the flow of air in the rotor could be detected. Thus, the prior art attempts to solve surging by injecting air upstream of the rotor have been somewhat misdirected since these attempts are aimed at preventing flow problems in the rotor area, when in fact the cause of the surging is first attributable to problems within the diffuser.

SUMMARY OF THE INVENTION

A surge controlling means for a centrifugal compressor having at least two stages, each of which comprise a rotor and diffuser is described. Air from one stage of the compressor is directed into the diffuser of a lower stage of the compressor through a collection chamber disposed about that diffuser. Control means are provided within a line which couples the collection chamber to a higher stage of compression to selectively allow the flow of air from the higher stage to the lower stage

when the flow of air to the compressor drops below a predetermined value.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates one prior art technique for preventing surging in a centrifugal compressor; said compressor is illustrated in a partial cutaway view;

FIG. 2 is a plan view of a two-stage compressor utilizing the surge control means of the present invention;

FIG. 3 is a partial cutaway view of the portion of the compressor shown in FIG. 2 generally along section line 3—3; and

FIG. 4 is a sectional view of the collection chamber, diffuser and rotor of the compressor illustrated in FIGS. 2 and 3.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, a typical centrifugal compressor for compressing a fluid such as air is illustrated along with a means used in the prior art for preventing surging. The compressor illustrated in FIG. 1 includes a first stage of compression 10 and a second stage of compression 20. The air or other fluid to be compressed enters the compressor through inlet 12, is then compressed within the first stage of compression 10, leaves the first stage of compression through outlet 16 and then enters the interstage heat exchanger 17. The air is typically cooled in between stages of compression and as illustrated in FIG. 1, the air leaving the heat exchanger 17 enters the second stage inlet 18 where it is compressed by the second stage of compression 20. The outlet air from outlet 19 of the second stage of compression 20 may then be used to perform numerous tasks as is presently done in the art such as driving pneumatic tools or may be compressed in additional stages of compression.

The first stage of compression 10 includes a rotor 14 and a volute diffuser 15. Likewise the second stage of compression 20 includes a rotor 22 and a diffuser 21. Both rotors 14 and 22 are directly connected to a drive shaft 28 which is rigidly coupled to a pinion gear 27. The power for the compressor is obtained from a motor 23 which is coupled to pinion gear 27 through bull gear 24, pinion gear 25 and bull gear 26.

The prior art surge control means illustrated in FIG. 1 includes an inlet valve 13, an outlet control valve 30, recirculating control valve 31 and a recirculating line 11. The recirculating line 11 interconnects the outlet 19 of the second stage of compression 20 with the inlet 12 of the first stage of compression 10. Valve 11 disposed within the recirculating line 11 controls the amount of outlet air which is recirculated within the compressor. The inlet valve 13 controls the amount of air which enters the compressor while the outlet valve 30 is used to control the outlet flow of air from the compressor.

Centrifugal compressors such as the one illustrated in FIG. 1 have a high efficiency while operating at a predetermined or optimum flow rate. In many applications a constant demand for air is not required and thus the flow of air from outlet 19 is not a constant. For example, where the air from the compressor is utilized to drive a plurality of pneumatic tools, the demand for air will be a function of the number of tools in operation and will be a variable. As previously explained, when the flow through the compressor is decreased below a predetermined value surging occurs. In the prior art

method for preventing surging illustrated in FIG. 1, air from the outlet 19 is fed into the compressor at the inlet to the first stage of compression 10. Typically control means sense the demand for air and as the demand decreases, valve 30 prevents all the air compressed by compressor stage 20 from leaving the compressor. Simultaneously valve 31 opens, allowing some of its air to enter the inlet of compressor stage 10 through line 11. Also the inlet air to compressor stage 10 is throttled by valve 13.

The surge control means illustrated in FIG. 1 has the disadvantage of wasting the energy utilized to compress the air in compressor stages 10 and 20. The high pressure air from outlet 19 when recirculated into the inlet 12, expands and is again recompressed within the compressor. Additionally, as previously explained, the injection of air by line 11 into the rotor 14 is intended to present the compressor surging associated with the rotor. Tests have indicated that in a typical centrifugal compressor the rotor is more tolerable to low flow conditions than is the diffuser. Thus, the prior art surge control technique illustrated in FIG. 1 has not provided a satisfactory surge control.

Referring to FIGS. 2 and 3, a compressor of substantially the same construction as the compressor of FIG. 1 is again illustrated but with a surge control means built in accordance with the present invention. The compressor comprises a first stage of compression 40 and a second stage of compression 50. Inlet air to the compressor enters through inlet 44, is then compressed by the first stage of compression 40, and is then delivered to the inlet 46 of the second stage of compression through line 45. Typically, a heat exchanger is coupled into line 45 so that the heat of compression from the first compression state 40 may be removed before the air is recompressed within the second stage of compression 50.

The first stage of compression includes a rotor 41 and a volute diffuser chamber 42 defined by manifold 52. The second stage of compression likewise includes a rotor and diffuser 43 which for the sake of clarity have not been illustrated in detail in FIGS. 2 or 3. The second stage of compression may be similar to the first stage of compression 40.

The driving means for the compressor includes a motor 64 which is directly connected to a bull gear 65. Bull gear 65 cooperatively engages and drives a pinion gear 66 which is axially mounted on a common shaft with a bull gear 67. Bull gear 67 cooperatively engages a pinion gear 68 which in turn drives drive shaft 69. The drive shaft 69 is coupled directly to the rotor 41 of the first state of compression 40 and may also be coupled to the rotor of the second stage of compression 50.

The compressor and in particular the rotor and diffuser may be built utilizing standard prior art techniques. While in FIGS. 2 through 4 the surge control means of the present invention is described in conjunction with a volute diffuser such as the one defined by manifold 52, it will be obvious to one skilled in the art that other types of diffusers such as a spiral diffuser may be utilized with the presently disclosed surge control means.

Referring to FIGS. 2, 3 and 4, a collection chamber 70 defined by a manifold 71 is axially disposed about one side of diffuser manifold 52. As best illustrated in FIG. 3, the collection chamber 70 is partly defined by the outer surface of manifold 52 and by manifold 71.

Manifold 71 abuts an inner radius of manifold 52. Orifices 63 disposed through manifold 52 allow the collection chamber 70 to communicate with the diffuser chamber 42. Referring particularly to FIG. 4, the orifices 63 are generally tangentially disposed through manifold 52 such that the air entering the diffuser chamber 42 will be injected into that chamber in the same direction as the direction of air forced into the chamber by rotor 41; that is, the air is injected into the chamber in the direction of the prevailing flow.

An inlet 54 formed by a portion of the collection chamber manifold 71 allows the inlet 54 to communicate with collection chamber 70. The diffuser return line 60 interconnects the outlet 62 of the second stage of compression 50 with the inlet 54 of the collection chamber 70. A valve 61 which is disposed within line 60 is used to throttle the air or other fluid which will flow from outlet 62 to the inlet 54.

The collection chamber 70 defined by manifold 71 with its inlet 54 may be an ordinary metal part manufactured utilizing known techniques. The line 60 and valve 61 may be standard components known and used in conjunction with fluid compressors.

When the compressor illustrated in FIGS. 2 through 4 is operating at its optimum or predetermined flow the valve 61 disposed within line 60 may be completely closed so that no air will flow from outlet 62 into inlet 54. As the flow from outlet 62 decreases below its optimum or a predetermined value, valve 61 opens, allowing air from the outlet 62 to flow into the collection chamber 70. The amount of air which is allowed to flow through line 60 is regulated by valve 61, and as the demand for air from the compressor is decreased more air is allowed to flow into the collection chamber 70. As the air enters the collection chamber 70 it is directed through the orifices 63 into the diffuser chamber 42 since it is at a higher pressure than the air in that chamber. It has been found that the injection of air into the diffuser will greatly decrease the effects of surging. Known means and techniques may be utilized to control valve 61 as a function of the outlet flow from the compressor. For example, a Pitot tube may be inserted within outlet 62 and utilized to operate valve 61.

While in FIGS. 2 through 4 the chamber 70 and orifices 63 are illustrated disposed along an inner radius of the diffuser manifold, it is of course within the scope of the present invention to place such chamber and orifices along the side of the diffuser or at any convenient location. Additionally, while the presently preferred embodiment has been illustrated as a two-stage compressor having stages of compression 40 and 50, it is within the scope of the present invention to utilize the presently disclosed surge control means with a compressor having any number of stages of compression. In such cases the air from any stage of compression except the first stage may be injected into the diffuser of any lower state of compression, as taught by the present invention. Also, in some applications it may be desirable to use the surge control means illustrated in FIGS. 2 through 4 in combination with some prior art surge control means such as the one illustrated in FIG. 1.

Thus, a surge control means for use with a centrifugal compressor has been disclosed wherein air from a higher stage of compression is injected into the diffuser of a lower stage of compression thereby preventing surging.

I claim:

1. In a centrifugal fluid compressor such as an air compressor having a plurality of stages of compression at least one of which includes a diffuser, surge control means for controlling surging in the compressor comprising:

a manifold coupled to said diffuser of one stage of compression defining a volume which communicates with said diffuser through orifices, said manifold including an inlet such that inlet fluid to said inlet enters said diffuser through said orifice;

a line coupled between said inlet of said manifold and a higher stage of compression than said one stage of compression such that fluid may be removed from said higher state of compression and injected into the diffuser of said one stage of compression.

2. The means for controlling surging defined in claim 1 wherein a control means, for controlling the flow of fluid in said line, is coupled to said line.

3. The means for controlling surging defined in claim 1 wherein said orifices are disposed such that fluid entering said diffuser from said volume is injected in the direction of the prevailing flow direction in said diffuser.

4. The means for controlling surging defined in claim 3 wherein said orifices are tangentially disposed through said diffuser.

5. In a centrifugal air compressor which includes a plurality of stages of compression, each stage comprising a rotor and diffuser, surge control means comprising:

a manifold defining a collection chamber disposed about the diffuser of one stage of compression said manifold having an inlet, and said collection chamber communicating with said diffuser through a plurality of orifices;

a line for transporting air, coupled between said manifold inlet and a stage of compression higher than said one stage of compression such that air from said higher stage of compression may be injected into the diffuser of said one stage of compression, and

control means for controlling the flow of air in said line as a function of the output flow of air from said compressor.

6. The surge control means defined in claim 5 wherein said orifices are disposed such that fluid entering said diffuser from said collection chamber is injected in the direction of the prevailing flow in said diffuser.

7. The surge control means defined in claim 6 wherein said orifices are tangentially disposed into said diffuser.

8. The surge control means defined in claim 7 wherein said compressor has two stages of compression.

9. The surge control means defined in claim 6 wherein said control means includes a valve disposed in said line.

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