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3,268,155

FLUID-FLOW CONTROL SYSTEM

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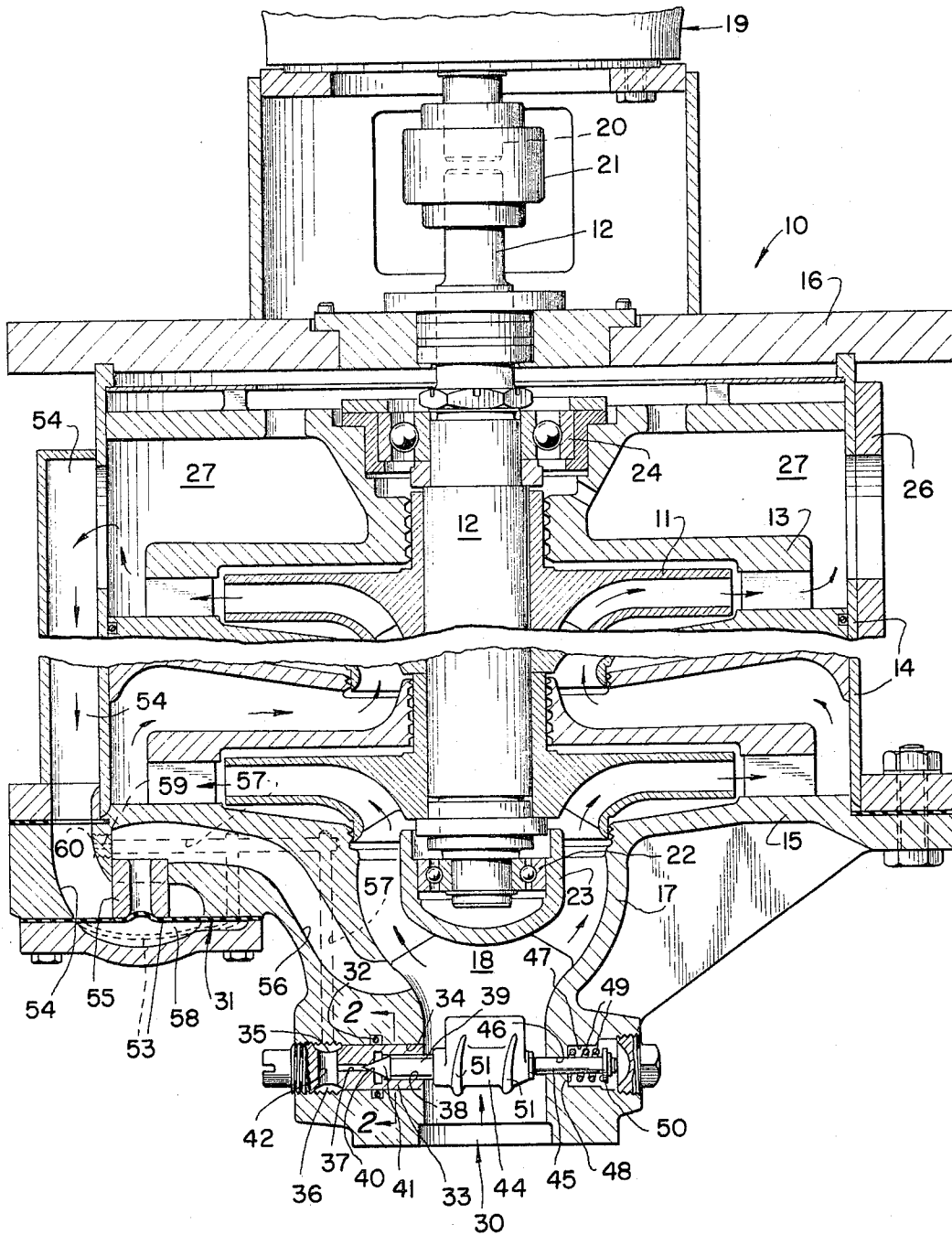


FIG. 1

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2 Sheets-Sheet 2

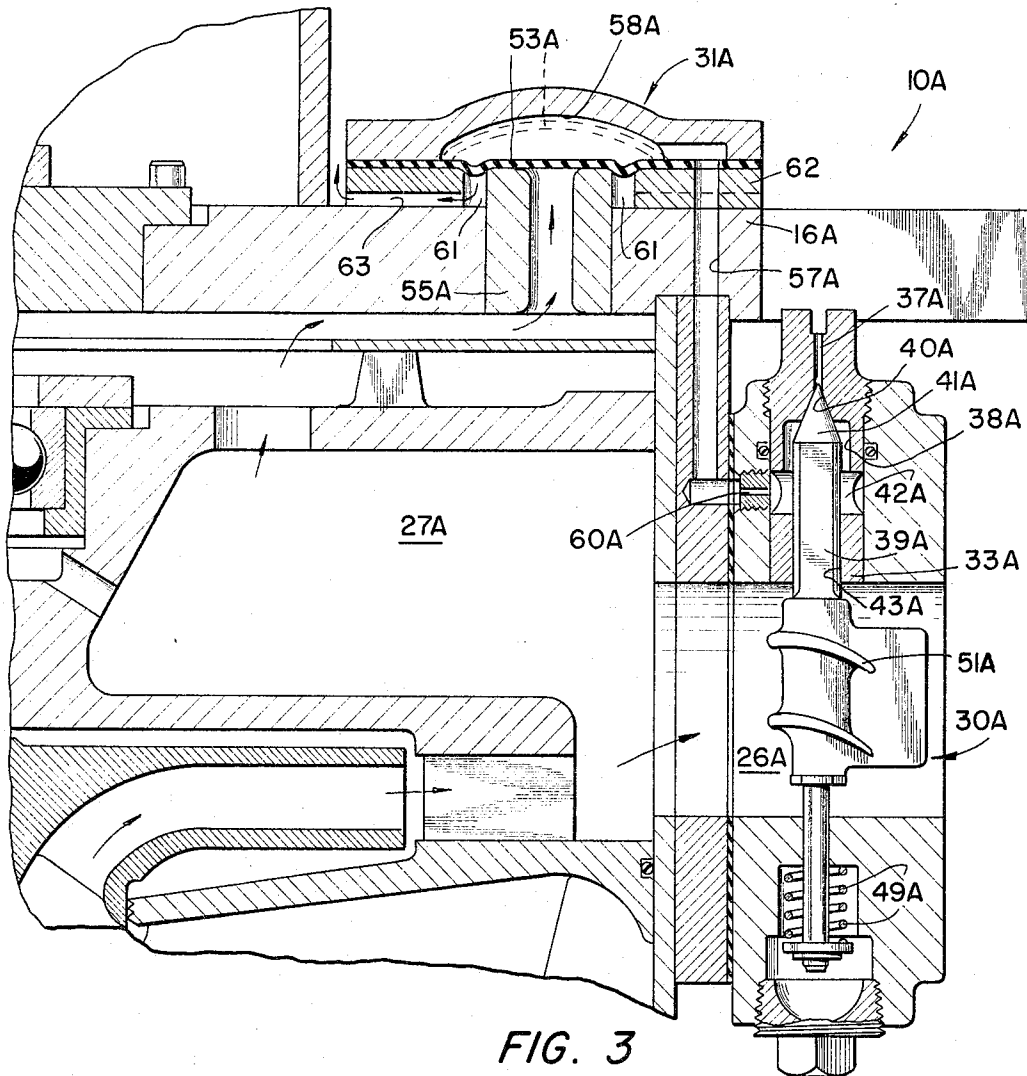


FIG. 3

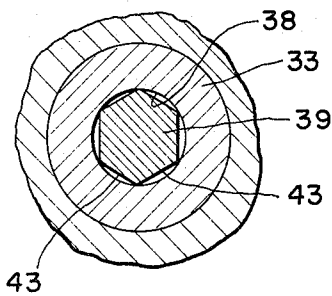


FIG. 2

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FLUID-FLOW CONTROL SYSTEM

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10 Claims. (Cl. 230-115)

This invention relates to a fluid-flow control system and more particularly to fluid control systems which can be employed in combination with a centrifugal compressor or pump to prevent the surging operation of the latter.

Heretofore, centrifugal compressors or pumps, such as blowers, could not be operated at light loads—as, for example, at 50% of capacity—because of a surging condition wherein compressed fluid at the discharge line breaks or surges back into the impeller chamber or chambers and results in a pulsating operation of the centrifugal compressor or pump. To avoid surging of a blower, complicated and expensive control systems have been developed. One type of fluid control system is disclosed in the U.S. patent to Jensen, No. 2,922,431.

It is, therefore, an object of the present invention to provide a fluid control system which is responsive to a mass flow of fluid and, in combination with a centrifugal compressor or pump, permits the operation of the centrifugal compressor or pump from zero capacity to full capacity without the surging condition of the operation occurring.

It is another object of this invention to provide a fluid control system for a centrifugal compressor or pump of relatively simple and inexpensive construction.

It is, therefore, contemplated by the present invention to provide, in a fluid control system, a pilot valve operative in response to the mass flow of fluid in a fluid-flow path to control the actuation of another valve to an open or closed position. The fluid control system in combination with a centrifugal compressor or pump, in one embodiment of the invention, is disposed at the inlet of a blower and functions to recirculate fluid from the outlet portion of the blower to the inlet of the blower to prevent the surging operation of the blower upon a predetermined mass flow of fluid through the inlet.

In another embodiment of the invention the flow control system is disposed at the outlet of the blower and functions to by-pass fluid from the outlet to the atmosphere upon a predetermined mass flow of fluid through the inlet to prevent the surging operation of the blower.

The invention will be more fully understood from the following detailed description thereof when considered in connection with the accompanying drawing wherein two embodiments of the invention are illustrated by way of example and in which:

FIG. 1 is a view in longitudinal cross section of a blower having a fluid control system according to one embodiment of this invention;

FIG. 2 is a fragmentary sectional view taken along line 2—2 of FIG. 1, somewhat enlarged; and

FIG. 3 is a fragmentary view in cross section of a blower, similar to that shown in FIG. 1, having a fluid control system according to another embodiment of the present invention.

Now referring to the drawings and more particularly to FIG. 1, the reference number 10 generally designates a low speed, multi-stage centrifugal blower which comprises a plurality of compressing or pumping stages constructed and arranged to provide a series flow of fluid therethrough. Each compressing stage consists of an impeller 11, keyed to a drive shaft 12, and a stator 13. The impellers and stators are disposed in a cylindrical housing or casing 14, one end of which is closed by a wall 15

while the opposite end is closed by a wall 16. End wall 15 is provided with an integral inlet connection 17 which defines an axially extending inlet passage 18. End wall 16 supports a motor 19 for rotating drive shaft 12 which projects through an opening in end wall 16. Drive shaft 12 is connected to the motor shaft 20 by a coupling 21 and at the opposite end is journaled in a bearing 22 disposed in a bearing support 23. Adjacent end wall 16, drive shaft 12 is journaled in a bearing 24 mounted in the endmost outlet stator 13. An outlet connection 26 is disposed in casing 14 and in communication with the outlet chamber 27 of stator 13.

To prevent the surging of blower 10, a fluid control system is provided. The fluid control system comprises a control or pilot valve assembly 30, a by-pass valve 31, a by-pass passage, and equalizer lines.

The pilot valve assembly 30 is disposed in inlet connection 17 and extends across inlet passage 18. Pilot valve assembly 30 comprises a valve seat member 33 turned into a partially threaded bore 34. Valve seat member 33 has a reduced diameter portion 35 intermediate the ends thereof, which portion defines with bore 34 an annular chamber 36. An axial bore 37 is provided in valve seat member 33, which bore is counterbored at 38 to receive a polygonal-shaped needle valve stem 39. At the juncture of bore 37 and counterbore 38, a valve seat 40 is formed to receive in abutment therewith a conical head 41 of needle valve stem 39. A transversely extending hole 42 is provided in the reduced diameter portion 35 of the valve seat member to communicate bore 37 with annular chamber 36. As best shown in FIG. 2, the surface of counterbored portion 38 and the flat side surfaces of valve stem 39 define a plurality of passages 43 which effect communication of bore 37 with inlet passage 18 when needle valve stem 39 is off seat 40. A seal 32 is disposed in the interstices between the surface of valve seat member 33 and bore 34 to prevent the flow of fluid therethrough.

The pilot valve assembly 30 further includes an actuator element 44 which is connected to needle valve stem 39 and is supported in inlet passage 18 by needle valve stem 39 and a stem 45. Stem 45 is slidably receivable in a bore 46, provided in inlet connection 17, in axial alignment with counterbored portion 38. Bore 46 is counterbored at 47 to form an annular shoulder 48. A spring 49 is disposed around stem 45 with one end thereof bearing against shoulder 48 and the other end against a washer 50 which is secured to the distal end of stem 45. Spring 49 functions to bias needle valve stem 39, stem 45, and actuator element 44 in a direction to unseat head 41 from seat 40. The actuator element 44 has a plurality of laterally extending wings or foils 51, each of which is of air-foil configuration. The foils 51 are so arranged that they resolve the mass flow of fluid through inlet passage 18 into a force directed along the axes of stems 39 and 45 to urge needle valve stem 39 against seat 40 in opposition to the tension of spring 49.

By-pass valve 31, comprising a flexible diaphragm 53 of any suitable construction, such as rubber, neoprene, or Teflon fabric-reinforced membrane, is disposed in a recirculation-line 54 which extends from end wall 15 to end wall 16 and communicates adjacent end wall 16 with outlet chamber 27. Diaphragm 53 seats against a hollow cylinder 55 which communicates recirculation-line 54 with one end of a by-pass passageway 56 formed in end wall 15, passageway 56 communicating at the opposite end with inlet passage 18. An equalizer line 57 is provided in end wall 15 in communication at one end with chamber 36 and at the opposite end with chamber 58 and recirculation-line 54. A plug 59 containing a restricting passage 60 is secured in the end of equalizer line 57 ad-

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jacent line 54. Restricting passage 60 is of a smaller flow capacity than bore 37 of pilot valve 30. Equalizer line 57 functions with the pilot valve 30 in a closed position to maintain chamber 58 at outlet pressure so that a differential pressure across diaphragm 53 is provided to hold the diaphragm seated against cylinder 55 and by-pass passageway 56 out of communication with line 54.

In the operation of the fluid control system, pilot valve 30 is first adjusted to a predetermined unseating force by selecting a spring 49 capable of imposing on the pilot valve a force of such magnitude as to effect movement of the pilot valve in a direction to unseat needle valve stem 39 from seat 40 upon a predetermined minimum mass flow of fluid that can pass through inlet passage 18 before centrifugal blower 10 enters into a surging condition of operation. Therefore, in the operation of the centrifugal blower at capacities above the point at which surging will occur, pilot valve 30 is maintained in a closed position by reason of the force exerted by foils 51 being greater than the force of spring 49 acting in the opposite direction. With pilot valve 30 closed, the fluid pressure in by-pass passageway 56 and the interior of cylinder 55, which pressure is inlet pressure, is less than that of the pressure (outlet pressure) in chamber 58 so that the diaphragm is held seated against cylinder 55 to keep by-pass passageway 56 out of communication with recirculation-line 54. When the mass flow of fluid through inlet passage 18 reaches the predetermined minimum value, spring 49 overcomes the force exerted by foils 51, which spring force urges the pilot valve in an open position; and pilot valve 30 is moved axially to unseat head 41 of needle valve stem 39 from seat 40. With pilot valve 30 open, inlet passage 18 is brought into communication with chamber 58 through line 57, chamber 36, hole 42, bore 37, and passages 43. Since chamber 58, line 57, chamber 36, and bore 37 are under a fluid pressure greater than the fluid pressure in inlet passage 18 when pilot valve 30 is closed, opening pilot valve 30 causes the pressure to be released from chamber 58 so that the fluid pressure in chamber 58 drops to substantially that of the pressure of the fluid in inlet passage 18. With the pressure in chamber 58 at the inlet fluid pressure and recirculation-line 54 at the outlet fluid pressure, a pressure differential across diaphragm 53 is created, which pressure differential unseats diaphragm 53 to bring line 54 into communication with by-pass passageway 56 so that the fluid is recirculated from the pump outlet to inlet passage 18 in quantities necessary to relieve the back pressure and to prevent the fluid from surging back through the impellers.

Since restricting passage 60 is of a smaller flow area than bore 37, the flow capacity of equalizer line 57, chambers 36 and 58, hole 42, and bore 37, the fluid will exhaust from those lines and chambers faster than the fluid can flow through passage 60; and, therefore, the diaphragm will be maintained unseated from cylinder 55 as long as pilot valve 30 remains open.

When the mass flow increases above the predetermined minimum value, the force exerted by foils 51 becomes great enough to overcome the force of spring 49 and needle valve stem 39 is moved axially to bring head 41 against seat 40 and thereby close pilot valve 30. With pilot valve 30 closed, the outlet fluid pressure flowing into equalizer line 57, through passage 60, soon increases the pressure in equalizer line 57, chambers 36 and 58, hole 42, and bore 37 to the outlet fluid pressure. With chamber 58 again at the outlet pressure, diaphragm 53 is flexed against cylinder 55 and held thereagainst until the pilot valve again is moved to an open position.

Alternative embodiment

In the alternative embodiment shown in FIG. 3, the fluid control system is disposed at the outlet of the centrifugal blower. In this embodiment surging is prevented by the fluid control system which functions to

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discharge the fluid to the atmosphere rather than to recirculate the fluid as in the embodiment shown in FIG. 1.

The fluid control system shown in FIG. 3 comprises a pilot valve 30A, similar to pilot valve 30, for controlling the actuation of a by-pass valve 31A, which is similar in construction to the by-pass valve 31 shown in FIG. 1. Accordingly, parts of the embodiment shown in FIG. 3, which are similar to parts of the embodiment shown in FIG. 1, will be designated by the same reference numbers with the suffix A added thereto.

As shown in FIG. 3, pilot valve 30A is disposed in the outlet passage 26A of a centrifugal blower 10A, while by-pass valve 31A is mounted on an end wall 16A.

The pilot valve 30A is of the same construction as pilot valve 30 except that the valve seat member has been modified. Valve seat member 33A has a bore 37A and a counterbored portion 38A. A valve seat 40A is provided on the juncture of bore 37A and counterbored portion 38A, which seat is adapted to receive in abutment therewith the head 41A of the needle valve stem 39A. The end of bore 37A opposite from seat 40A communicates with the atmosphere. A transverse hole 42A is disposed in the valve seat member upstream from seat 40A and in communication with the outlet passage 26A through the passages 43A formed between the flat side surfaces of needle valve stem 39A and the surface of counterbored portion 38A. Hole 42A also communicates with an equalizer line 57A through a restricting passage 60A, the opposite end of equalizer line 57A being in communication with a chamber 58A formed on one side of the diaphragm 53A of by-pass valve 31A. The bore 37A, thus, communicates with the equalizer line 57A to bleed the latter to atmosphere when the head 41A of the needle valve stem 39A is displaced from the valve seat 40A. In order to permit this bleeding of the equalizer line 57A, the passages 43A are, of course, formed with a collective flow area that is less than the flow area of the bore 37A.

The diaphragm 53A is adapted to seat against a hollow cylindrical member 55A and control the fluid flow through the latter and an annular vent port 61 concentric to cylindrical member 55A. Vent port 61 is formed in a plate 62 suitably secured to end wall 16A of the centrifugal blower. A vent line 63 is provided in plate 62 to communicate vent port 61 with the atmosphere. The interior of cylindrical member 55A is in communication with the outlet chamber 27A of centrifugal blower 10A.

In the operation of the fluid control system shown in FIG. 3, at a mass flow of fluid through outlet chamber 27A and outlet passage 26A above that at which surging would normally occur, diaphragm 53A is held in sealing relationship with vent port 61 by the differential pressure across diaphragm 53A. Chamber 58A of by-pass valve 31A is maintained at substantially the same pressure as the pressure of passage 26A through equalizer line 57A. Since the outlet pressure of the centrifugal blower is greater than the atmospheric pressure in vent port 61, diaphragm 53A is held in fluid-tight relation to vent port 61. When the capacity of the centrifugal blower is reduced so that the mass flow of fluid through outlet passage 26A is a predetermined value, which mass flow exists just prior to the surging operation of the blower, a spring 49A of pilot valve 30A overcomes the opposing force exerted by the foils 51A and moves pilot valve 30A downwardly, as viewed in FIG. 3, to unseat head 41A from seat 40A. With needle valve stem 39A in an unseated position, counterbored portion 38A and hole 42A are brought into communication with the atmosphere through bore 37A. When hole 42A is vented to the atmosphere, the pressure in chamber 58A is reduced by the flow of fluid therefrom through equalizer line 57A, restricting passage 60A, hole 42A, counterbored portion 38A, and bore 37A. This provides a greater pressure in the interior of cylindrical member 55A than in cham-

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ber 58A so that diaphragm 53A is flexed to the broken-line position and communicates outlet chamber 27A with the atmosphere through vent port 61 and vent line 63. With outlet chamber 27A communicating with the atmosphere, sufficient fluid is by-passed to the atmosphere to relieve the back pressure and prevent the surging operation of centrifugal blower 10A.

When the mass flow of fluid in outlet passage 26A increases above the predetermined value, the force exerted by foils 51A overcomes the force of spring 49A and pilot valve 30A moves to seat head 41A on seat 40A, thereby closing bore 37A. With bore 37A closed to the atmosphere, the pressure in chamber 58A is increased by the flow of fluid at the outlet pressure through passages 43A, hole 42A, and restricting passage 60A to provide a differential pressure across diaphragm 53A, which differential pressure forces the diaphragm to seat against vent port 61. When vent port 61 is closed, outlet chamber 27A is out of communication with the atmosphere and no fluid is by-passed to the atmosphere.

It is now believed readily apparent that the present invention provides a novel fluid flow control system having a valve controlled by a pilot valve which is automatically responsive to the mass flow of fluid. It is a fluid-flow control system of relatively inexpensive and simple construction which, in combination with a centrifugal compressor or pump, prevents the surging operation at low load conditions by relieving back pressure at the discharge of the pump either to the atmosphere or to the inlet of the pump.

Although two embodiments of the invention have been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes can be made in the arrangement of parts without departing from the scope and spirit of the invention as the same will now be understood by those skilled in the art.

I claim:

1. In a centrifugal compressor or pump having an inlet and an outlet, a fluid-flow control system comprising
 - (a) a recirculation-line communicating at one end with the outlet and at the opposite end with the inlet of the pump,
 - (b) a recirculation-valve disposed in said recirculation-line and responsive to a differential pressure in said recirculation-line to control the flow of fluid there-through,
 - (c) a pilot valve associated with said inlet to be operative in response to the mass flow of fluid through said inlet,
 - (d) said pilot valve connected to said recirculation-valve to effect actuation of the latter to allow the flow of fluid through said recirculation-line when the pilot valve is operative in response to a predetermined mass flow of fluid through said inlet, and
 - (e) an equalizer line communicating with said outlet to receive fluid at a pressure substantially that of the fluid flowing through said outlet,
 - (f) said equalizer line being connected to conduct such fluid to said recirculation-valve, while said pilot valve is closed, to provide for balanced pressures on said recirculation-valve and, upon opening of said pilot valve, to communicate said recirculation-valve with the inlet pressure and conduct the fluid from said recirculation-valve to unbalance the pressures there-on.
2. The apparatus of claim 1, wherein a mass flow responsive means is disposed in said inlet and connected with said pilot valve for operating the latter.
3. The apparatus of claim 2, wherein a biasing means urges said pilot valve to an open position, said mass flow responsive means actuates said pilot valve to a closed position, and said mass flow responsive means comprises an airfoil disposed in said inlet.
4. In a centrifugal compressor or pump having an

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inlet and an outlet, a fluid-flow control system comprising

- (a) a recirculation-line communicating at one end with the outlet and at the opposite end with the inlet,
- (b) a recirculation-valve having a flexible diaphragm which is subject to flexure when exposed to a differential pressure to permit the flow of fluid through said recirculation-line,
- (c) an equalizer line communicating with said recirculation-line and to one side of the diaphragm to subject the diaphragm to a differential pressure, and
- (d) a pilot valve associated with said inlet to be responsive to the flow of fluid therethrough for controlling the flow of fluid in said equalizer line,
- (e) said pilot valve being responsive to a predetermined mass flow of fluid through said inlet to permit the flow of fluid through said equalizer line and thereby unbalance the pressures across said diaphragm to cause the latter to flex and thereby permit the flow of fluid through said recirculation-line.
5. The apparatus of claim 4, wherein a biasing means and a mass flow responsive means which is disposed in said inlet and connected with said pilot valve are provided for controlling the operation of said pilot valve.
6. The apparatus of claim 5, wherein said biasing means urges said pilot valve to an open position and said mass flow responsive means comprises an airfoil disposed in said inlet for urging said pilot valve to a closed position.
7. In combination with a centrifugal compressor having a fluid inlet and a fluid outlet, a fluid-flow control system comprising
 - (a) a recirculation-line communicating at one end with the outlet and at the opposite end with the inlet of the compressor to conduct the fluid from the outlet to the inlet of the compressor,
 - (b) a flexible diaphragm valve disposed intermediate the ends of said recirculation-line and movable, in response to a differential pressure, to a position whereby the flow of fluid through said recirculation-line is permitted,
 - (c) an equalizer line communicating with said recirculation-line to receive outlet fluid from the latter and with one side of said diaphragm valve to conduct outlet fluid to the latter,
 - (d) said equalizer line communicating with said fluid inlet,
 - (e) a pilot valve controlling the flow of fluid in said equalizer line to said fluid inlet,
 - (f) means for biasing the pilot valve to an open position so that the equalizer line is in communication with the fluid inlet, and
 - (g) a mass flow responsive means disposed in said fluid inlet and connected with said pilot valve for exerting a force counter to said biasing means to urge the pilot valve to a closed position,
 - (h) said biasing means being of a predetermined force to overcome the force exerted by said mass flow responsive means to open said equalizer line to said fluid inlet at a predetermined mass flow of fluid through said fluid inlet to thereby cause a differential pressure in said diaphragm valve and cause the latter to actuate to a position whereby the flow of fluid through said recirculation-line is permitted.
8. The apparatus of claim 7, wherein said mass flow responsive means comprises an airfoil means, and said pilot valve comprises a needle valve.
9. In a centrifugal blower having a fluid inlet and a fluid outlet, a fluid-flow control system comprising
 - (a) a vent line communicating at one end with the outlet of the blower and at the opposite end with the atmosphere,
 - (b) a vent valve disposed intermediate the ends of said vent line to control the flow of outlet fluid to the atmosphere through said vent line,
 - (c) said vent valve having a diaphragm responsive to

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a differential pressure thereacross to prevent in one position the flow of fluid through said vent line and in the other position permit the flow of fluid through said vent line,

- (d) an equalizer line communicating with the outlet 5 to receive the fluid from the latter and with said vent valve to provide a differential pressure to position said vent valve to prevent the flow of fluid through the vent line, and
- (e) a pilot valve communicating with said outlet to 10 be responsive to the mass flow of fluid through the outlet of said blower,
- (f) said pilot valve being associated with said equalizer line to communicate the latter with the atmosphere 15 upon the actuation of the pilot valve in response to a predetermined mass flow of fluid through said outlet of the blower to thereby cause the vent valve to actuate to a position whereby the flow of fluid through the vent line is permitted.

10. The apparatus of claim 9 wherein said pilot valve comprises a needle valve, a biasing means urging said needle valve to an open position, and airfoil means for

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converting the mass flow of fluid into a force counter to the force of said biasing means.

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