S. A. MOSS.

PULSATION PREVENTING APPARATUS FOR CENTRIFUGAL COMPRESSORS.

APPLICATION FILED FEB. 2, 1917.

**1,280,811.**

Patented Oct. 8, 1918.

2 SHEETS—SHEET 1.

Fig. 1.

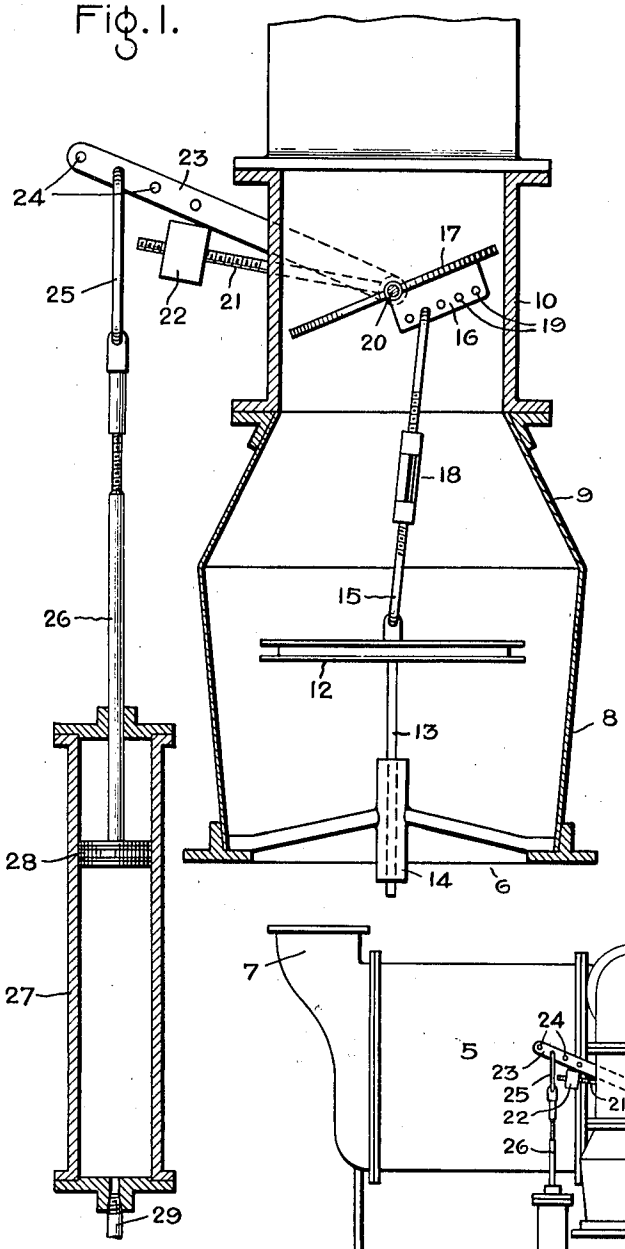



Fig. 2.




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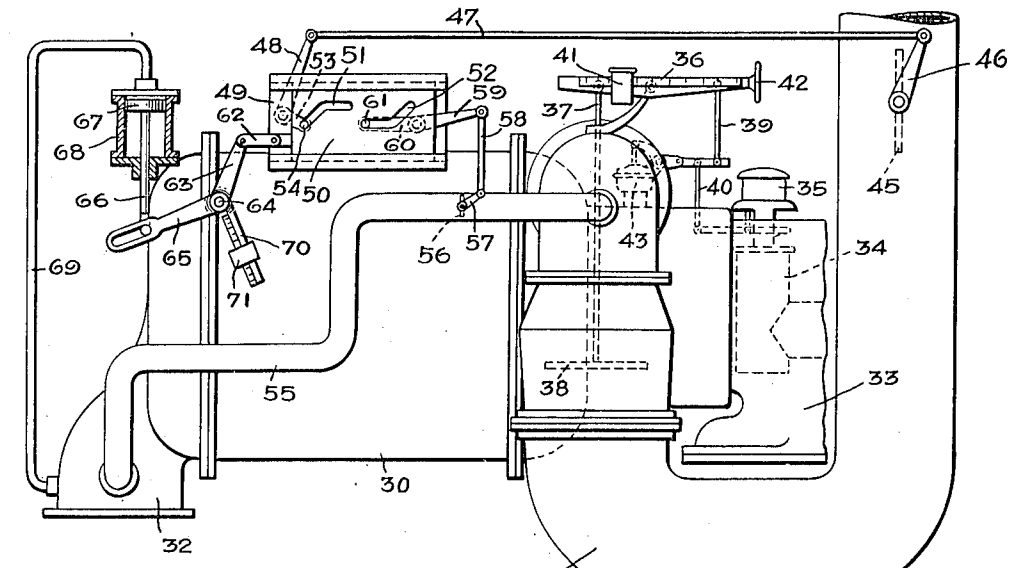



Fig. 3.

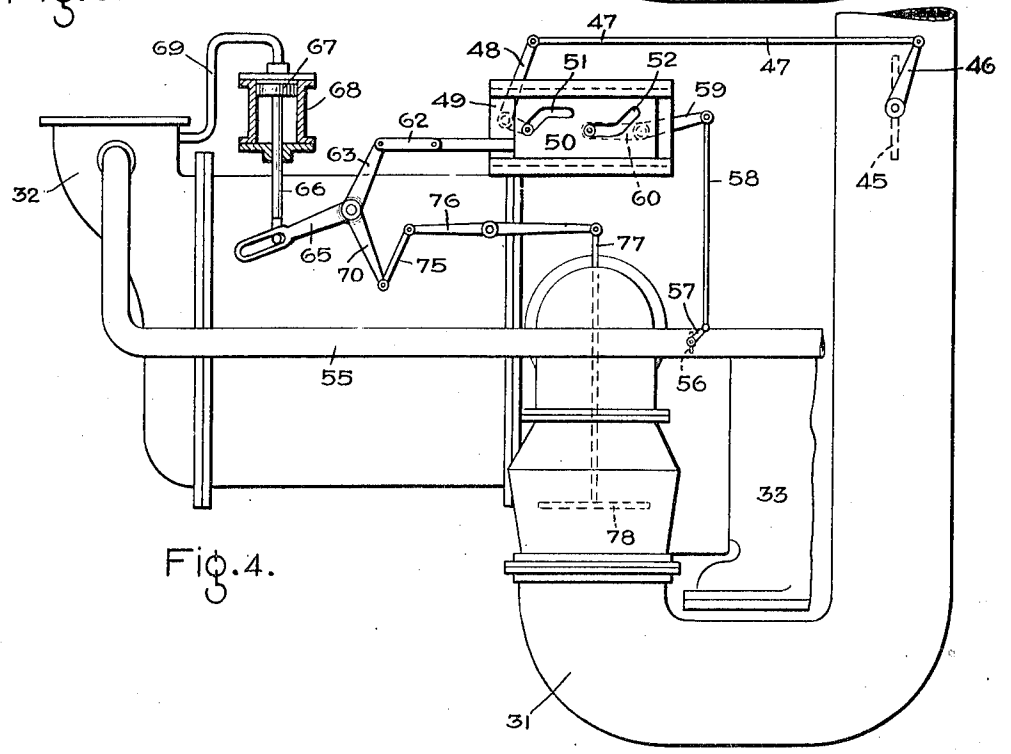



Fig. 4.

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# UNITED STATES PATENT OFFICE.

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## PULSATION-PREVENTING APPARATUS FOR CENTRIFUGAL COMPRESSORS.

1,280,811 Specification of Letters Patent. Patented Oct. 8, 1918.

Application filed February 2, 1917. Serial No. 146,127.

*To all whom it may concern:*

Be it known that I, SANFORD A. MOSS, a citizen of the United States, residing at Lynn, in the county of Essex, State of Massachusetts, have invented certain new and useful Improvements in Pulsation-Preventing Apparatus for Centrifugal Compressors, of which the following is a specification.

The present invention relates to centrifugal compressors such as are used for compressing air, or other gases, and has for its object generally to provide an improved apparatus for preventing pulsations of the air or other gas flowing through the machine.

In the following specification the compressor is described as a machine handling air, but it will be understood that my invention is not limited to this use.

Pulsations are found to occur under certain conditions of light load and are now known to depend on the volume of air which the machine is handling and on the pressure at which it is being delivered. In other words, for every volume there is a critical pressure above which pulsations are liable to occur; and vice versa for every pressure there is a critical volume below which pulsations are liable to occur. The critical pressures and volumes in different machines vary considerably, however, and for any particular machine they can only be determined by experiment.

As already stated, the point at which pulsations occur depends on the volume and the pressure, which in turn are proportional to the speed of the machine, and the "ratio of volume to speed", or approximately "ratio of volume to square root of the pressure" is known as the "load coefficient" of a compressor. If this coefficient is relatively large, the machine will operate smoothly; but if it decreases below a certain value then pulsations will occur. There is thus for every compressor a critical valve of the load coefficient below which pulsations will occur. This varies for different machines and can only be determined by experiment.

It is well known that pulsations in a compressor may be prevented, at least to a great extent, by throttling the flow of air through it, as by throttling the intake, or by wasting air from the delivery side of the machine, or by by-passing it from the delivery side to the intake. In installations where it is desirable that the machine be operated at loads where pulsations are liable to occur such valves are usually provided. Such valves may be termed generically pulsation preventing valves, and they have been actuated manually and by various automatic arrangements.

It is also now known, as set forth in the application of Christopher A. Schellens, Serial No. 146,112, filed of even date herewith, that in order to prevent pulsations the pulsation preventing valve should be actuated in accordance with the value of the volume divided by the square root of the pressure, *i. e.*, in accordance with the load coefficient of the machine. If so actuated such valve would be actuated by just the right amount and under the proper conditions to prevent pulsations occurring. As will be appreciated, the operation of the pulsation preventing valve, as the throttling of a valve in the intake, or the opening of a by-pass valve, or both, is desirable only when necessary as it means, of course, a loss of energy.

More specifically the object of my invention is to provide an improved arrangement which is applicable under varying conditions to prevent the occurrence of pulsations.

For a consideration of what I believe to be novel and my invention, attention is directed to the accompanying specification and the claims appended thereto.

In the accompanying drawings, Figure 1 is a vertical sectional view of a pulsation preventing apparatus embodying my invention; Fig. 2 shows the apparatus of Fig. 1 applied to a centrifugal compressor; Fig. 3 illustrates a modified form of my invention wherein the same is applied to a compressor operating under a condition different from that shown in Figs. 1 and 2, and Fig. 4 shows another form of my invention.

Referring to the drawings, Figs. 1 and 2, 5 indicates a centrifugal compressor having an inlet conduit 6 and a discharge conduit 7. It

may be driven by any suitable form of prime mover, as for example, a steam turbine. The inlet conduit 6 comprises an enlarged section formed of two conical-shaped members 8 and 9 and a straight section 10 which connects the conical member 9 to an elbow 11 leading to the eye of the impeller. Located in the enlarged section is a float 12 which rides on the incoming air and, as is explained more fully hereinafter, tends to assume a position which varies with the volume entering the compressor. The float 12 is guided by a stem 13 which slides in a guide sleeve 14 and it is connected by a link 15 to a plate 16 carried by a butterfly valve 17 which is located in the pipe section 10. The link 15 is preferably arranged so that its length may be adjusted, and to this end it is shown as being provided intermediate between its ends with a turn buckle 18. The butterfly valve 17 is adapted to throttle the intake of the compressor to prevent the occurrence of pulsations. The plate 16 is provided with a series of openings 19, into any one of which the end of link 15 may be connected. By this arrangement the float 12, while having one movement, may be set so that it tends to impart a desired characteristic movement to the valve 17. 20 indicates the spindle of the valve journaled in the wall of pipe section 10. On an extension of one end of the spindle 20 is fixed a rod 21 carrying an adjustable weight 22 which tends to bias the butterfly valve to open position, and an arm 23 having a series of openings 24 in its end. Connected into one of the openings 24 is one end of a link 25, the other end of which is adjustably connected to a stem 26 carried by the movable element of a pressure responsive device. In the present instance this pressure responsive device is shown as comprising a cylinder 27 within which moves a piston 28, to which stem 26 is connected, such piston forming a movable abutment. Connected with cylinder 27 below piston 28 is a pipe 29 which leads to the discharge side of the compressor. The movable abutment 28 is thus subjected to the pressure on the delivery side of the compressor.

With the arrangement as just described it will be seen that the butterfly valve 17 is subjected to two positioning forces; one proportional to the volume and represented by the force exerted by the float 12, and the other proportional to the delivery pressure and represented by the force exerted by the movable abutment 28. These two forces act on opposite sides of the spindle 20 and are thus opposed to each other.

As stated above, it is now known that in order to prevent pulsations the pulsation preventing valve should be actuated in accordance with the volume divided by the square root of the pressure. Now for centrifugal machinery at a given load coefficient, the pressure varies with the square of the speed, so that the value of volume squared divided by pressure is given by the volume divided by the square root of pressure; *i. e.*, the load coefficient. In fact one is the square of the other.

In the operation of my apparatus the float 12 is connected to the butterfly valve 17 at such an obliquity of the link 15 and the float force so varies with the volume that the float exerts an opening force upon the butterfly valve spindle which is proportional to the square of the volume, and the movable abutment 28 is connected to the valve 17 through the arm 23 so that it exerts a closing force proportional to the delivery pressure. The resultant force acting on the valve 17 is thus proportional to the volume squared divided by pressure, which in turn is proportional to the load coefficient. The arrangement is such that for all values of the load coefficient above the critical value the valve is wide open. When the critical value of the load coefficient is reached then the apparatus will operate the butterfly valve to throttle the inlet by a sufficient amount to maintain the load coefficient at, or just slightly above, the critical value. As already pointed out, the critical load coefficient value is determined experimentally for each machine. The arrangement may be termed a universal automatic pulsation preventing apparatus, as it automatically takes account of both the volume and the pressure in the actuation of the pulsation preventing valve.

I have found by experiments that throttling the intake of a compressor will prevent pulsations down to a certain low flow, after which further throttling will not prevent them. The only means of which I am now aware for then preventing pulsation is by wasting air from the delivery side of the compressor or by by-passing it from the delivery to the suction side thereof, the latter arrangement being generally preferable. In Figs. 3 and 4 I have shown arrangements for preventing pulsations wherein a throttle valve in the intake is first operated and after it becomes ineffective to prevent pulsations then a waste or by-pass valve is opened to waste air from the delivery side of the compressor or by-pass it therefrom to the suction side of it.

Referring now to Fig. 3, 30 indicates a centrifugal compressor having an inlet conduit 31 and a discharge conduit 32. It is shown as being driven by a steam turbine, a portion of which is indicated at 33. 34 indicates the valve mechanism which controls the admission of elastic fluid to the turbine, and 35 a fluid actuated motor for operating it. The turbine driven compressor set is provided with a usual form of constant vol-

ume governor comprising a pivoted beam 36 connected at one end by a rod 37 to a float 38 in the inlet conduit 31. The other end of beam 36 is connected through links 39 and 40 to the fluid motor 35. 41 indicates the constant volume governor weight and 42 the hand wheel for adjusting it along the scale on the beam. The fluid motor 35 is also suitably connected to the speed governor 43 as shown. The operation of a constant volume governing mechanism, as just described, is well known. The weight 41 is set on the scale for the desired volume of flow and the float 38 acts on the beam to tilt it so as to cause the fluid motor 35 to open and close the valve mechanism 34 to maintain the turbine 33 at the speed required to supply the volume of air desired. If the volume of air flowing tends to decrease, then the float 38 lowers a little, thus causing the beam 36 to tilt and open the valve mechanism 34 so as to admit more elastic fluid to the turbine and increase the speed, and thus cause the compressor to take more air. On the other hand, if the volume tends to increase then the opposite action takes place. The speed governor 43 is normally inactive, the turbine being wholly under the control of the constant volume governor, and only comes into play to take control in case of excess speed. It is somewhat of the nature of an emergency governor.

45 indicates a butterfly valve in the inlet conduit, and 46 an operating arm for it. The free end of arm 46 is connected by a rod 47 to an arm 48 of a bell crank lever, which lever is pivoted on a frame 49. Sliding in guides on the frame 49 is a cam plate 50 provided with cam slots 51 and 52 each comprising an angular portion and a straight portion. The other arm 53 of the bell crank lever has a pin or roller 54 at is end which projects into the slot 51. 55 indicates a pipe for wasting air from the discharge side of the compressor. It is shown as connecting the discharge side of the compressor to the inlet in advance of the constant volume governor float 38, this being the preferred arrangement. In the pipe 55 is a butterfly valve 56 having an operating arm 57 connected by a rod 58 to one arm 59 of a bell crank lever pivoted on the frame 49. The other arm 60 of the bell crank lever has a pin or roller 61 at its end which projects into the cam slot 52. The cam plate 50 is connected by a link 62 to one arm 63 of a three-arm lever, which lever is pivoted at 64. A second arm 65 of the three-arm lever is connected to the end of a stem 66 carried by a piston 67 which moves in a cylinder 68. The end of cylinder 68 is connected by a pipe 69 to the discharge side of the compressor. The piston 67, which forms a movable abutment, is thus subjected to the pressure on the delivery side of the compressor. The third arm 70 of the three-arm lever has a scale thereon which is graduated in accordance with the square of the volume and carries a weight 71 adjustable to different positions thereon.

In operation the constant volume governor weight 41 is set for the desired volume of flow and the weight 71 is adjusted on the arm 70 to a position on the scale corresponding to this flow. The valve 45 in the inlet conduit 31 will be wide open and the valve 56 in conduit 55 closed. If now the load coefficient reaches a value at which pulsations are likely to occur, then the increased delivery pressure acting on the piston 67 will lower it, thereby turning the three-arm lever in an anti-clockwise direction. This will move the cam plate 50 toward the left and the pin or roller 54 on the end of bell crank lever arm 53 will ride up the inclined portion of cam slot 51 thus tilting the bell crank lever so that the end of lever arm 48 moves toward the left and closes to a greater or less extent the butterfly valve 45. This action may continue until a condition is reached when further throttling of valve 45 will not prevent pulsation. The pin or roller 54 then passes into the straight portion of cam slot 51 and throttle valve 45 is then upon further movement of cam plate 50 held stationary. During the movement of cam plate 50 and while the pin or roller 54 was moving up the inclined portion of cam slot 51, the pin or roller 61 was moving along the straight portion of cam slot 52, the valve 56 remaining closed. At or about the time the pin or roller 54 reached the straight portion of cam slot 51, the pin or roller 61 reached the angular portion of cam slot 52, and when it starts to ride up this angular portion, the bell crank lever of which it forms a part is turned on its pivot to open the by-pass valve 56. This permits air to be wasted from the delivery side of the compressor and prevents the occurrence of pulsations. By this arrangement, it will be seen that the pulsation preventing valves 45 and 56 act in sequence. This gives the most efficient operation of the compressor under the varying conditions of load.

Referring now to Fig. 4, I have shown the pulsation preventing valve mechanism of Fig. 3 applied to a compressor which is not equipped with a constant volume governor as is that of Fig. 3. The arrangement of Fig. 4 forms a universal pulsation preventing mechanism the same as does that of Figs. 1 and 2. In fact, it is the arrangement of Figs. 1 and 2 applied to the valve mechanism of Fig. 3. Since the arrangement of the valve mechanism of Fig. 3 is the same as that of Fig. 2 I have applied the same reference numerals to corresponding parts. The arrangement of Fig. 4 differs

from that of Fig. 3 in that the arm 70 of the three-arm lever instead of carrying a weight 71 has its free end connected by a link 75 to one arm of a lever 76. The other arm of the lever is connected by a rod 77 to a float 78 located in the intake conduit 31 the same as is the constant volume governor float 38, Fig. 3, and the float 12 of Fig. 1. The operation of the arrangement of Fig. 4 is the same as that of Figs. 1 and 2, the float 78 and pressure responsive device 67 both acting upon the pulsation preventing valve mechanism and in opposite directions. In the present instance, however, the pulsation preventing valve mechanism comprises the two valves 45 and 56, the one in the inlet 31 and the other in the by-pass 55, the two being operated in sequence. In view of the explanations already given of the operation of the arrangements of Figs. 1, 2 and 3, the operation of that of Fig. 4 will be readily understood without further description.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States, is:—

1. The combination with a centrifugal compressor having a pulsation preventing valve mechanism comprising a valve member, of means for automatically regulating said valve member comprising a float in the inlet of the compressor, a movable abutment responsive to the discharge pressure of the compressor, and means connecting the float and the abutment to said valve member so that said float acts in a direction to open the valve member and said movable abutment acts in a direction to close it.

2. The combination with a centrifugal compressor having a pulsation preventing valve mechanism comprising a valve member and a pivoted spindle, of means for automatically regulating it, comprising a float in the inlet of the compressor, a movable abutment responsive to the discharge pressure of the compressor, and means connecting the float and the abutment to said spindle so that said float acts in a direction to open the valve member and said movable abutment acts in a direction to close it.

3. The combination with a centrifugal compressor having a pulsation preventing valve mechanism comprising a valve member, of means for automatically regulating said valve member comprising a three-arm lever, means connecting one arm of said lever to the valve member, a float in the inlet of the compressor, a movable abutment subjected to the pressure on the delivery side of the compressor, and means connecting said float and abutment to the other two arms of said three-arm lever.

4. The combination with a centrifugal compressor having a pulsation preventing valve mechanism comprising a valve member, of means for automatically regulating said valve member comprising a float in the inlet of the compressor, a movable abutment responsive to the discharge pressure of the compressor, and means connecting the float and the abutment to said valve member in such manner that they act on the valve member in opposition to each other.

5. The combination with a centrifugal compressor having a by-pass conduit connected with the discharge end thereof, of a throttle valve in the inlet, a throttle valve in the by-pass conduit, a float in the inlet, a movable abutment subjected to the pressure on the delivery side of the compressor, and means connecting said float and abutment to the two valve mechanisms.

6. The combination with a centrifugal compressor having a by-pass conduit connected with the discharge end thereof, of a throttle valve in the inlet, a throttle valve in the by-pass conduit, a float in the inlet, a movable abutment subjected to the pressure on the delivery side of the compressor, and means connecting said float and abutment to the two valve mechanisms and operating to actuate them successively.

7. The combination with a centrifugal compressor having a by-pass conduit connected with the discharge end thereof, of a valve in the inlet, a valve in the by-pass conduit, a three-arm lever, means connecting one of said arms to the valves to operate them successively, a movable abutment subjected to the pressure on the delivery side of the compressor, means connecting said abutment to another of said arms, and means for subjecting said third arm to a force proportional to the volume passing through the compressor.

8. The combination with a centrifugal compressor having a by-pass conduit connected with the discharge end thereof, of a valve in the inlet, a valve in the by-pass conduit, a three-arm lever, means connecting one of said arms to the valves to operate them successively, said means comprising a plate having cam slots therein, a movable abutment subjected to the pressure on the delivery side of the compressor, means connecting said abutment to another of said arms, and means for subjecting said third arm to a force proportional to the volume passing through the compressor, the forces on the three-arm lever due to said abutment and said last named means acting in opposition to each other.

9. The combination with a centrifugal compressor having a by-pass conduit con-

nected with the discharge end thereof, of a valve in the inlet, a valve in the by-pass conduit, a three-arm lever, means connecting one of said arms to the valves to operate them successively, a movable abutment subjected to the pressure on the delivery side of the compressor, means connecting said abutment to another of said arms, a float in the inlet of the compressor, and means connecting said float to the third arm of said three-arm lever.

In witness whereof, I have hereunto set my hand this 19 day of January 1917.

SANFORD A. MOSS.