April 9, 1963 C. F. FRYE 3,084,707

EXHAUST VALVE

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FIG. 1

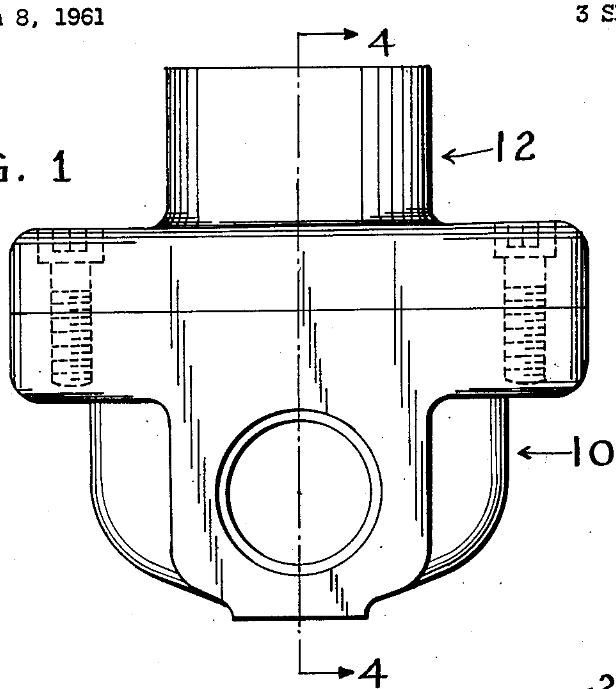


FIG. 2

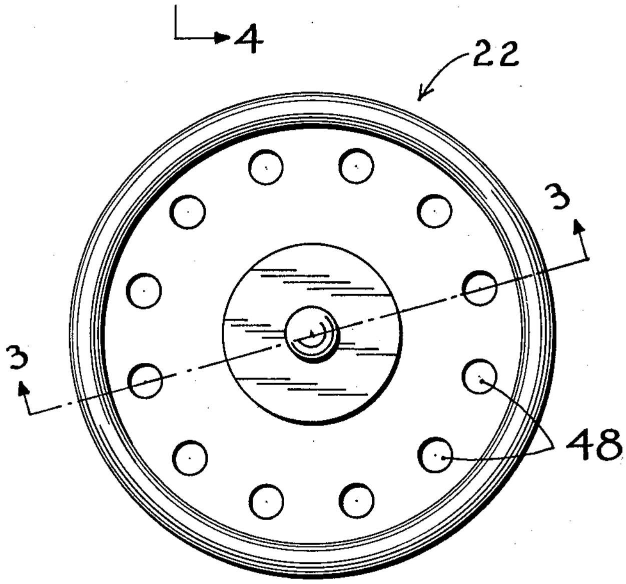
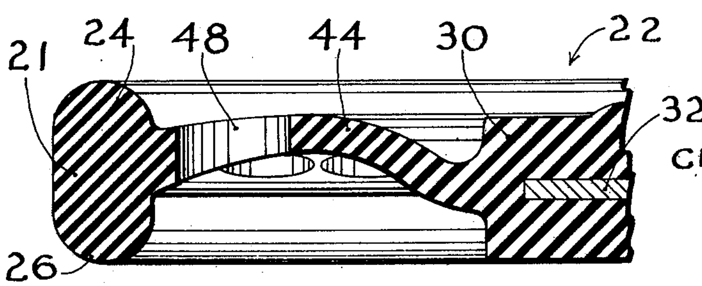


FIG. 3



INVENTOR.
CHARLES F. FRYE

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EXHAUST VALVE

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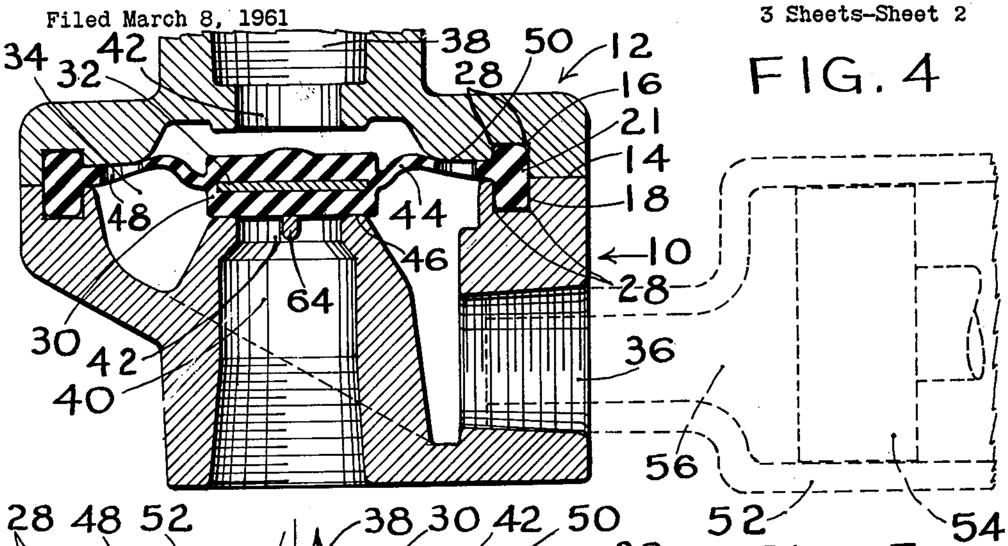

FIG. 4

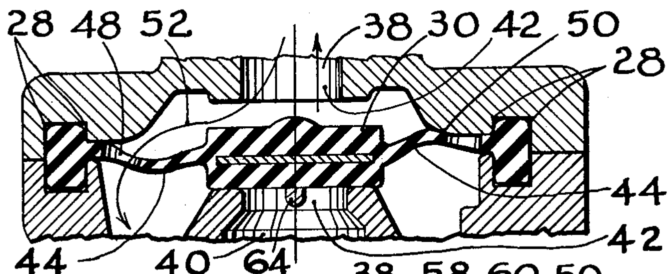

FIG. 5

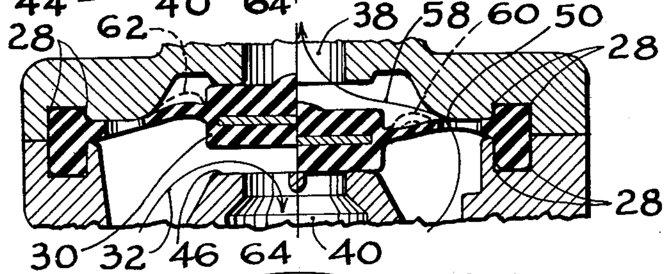

FIG. 6

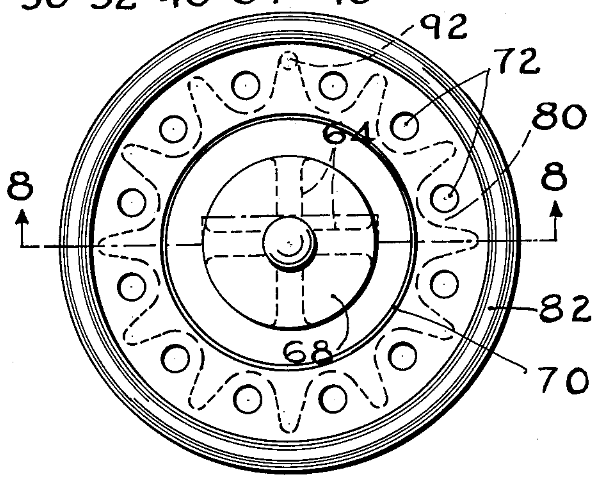

FIG. 7

INVENTOR.
CHARLES F. FRYE

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EXHAUST VALVE

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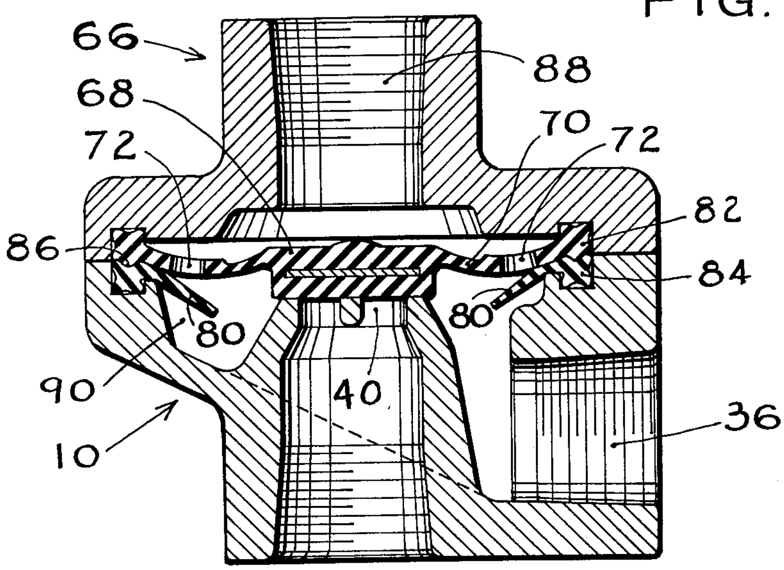

FIG. 8

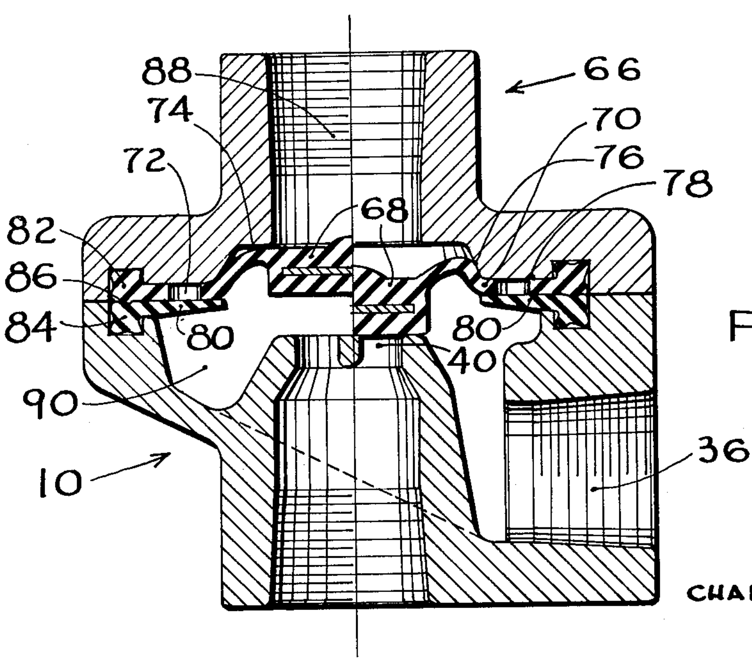

FIG. 9

INVENTOR
CHARLES F. FRYE

United States Patent Office

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EXHAUST VALVE

Charles F. Frye, Fort Lauderdale, Fla.; Continental Illinois National Bank and Trust Company of Chicago and Robert A. Elliott, executors of said Charles F. Frye, deceased

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6 Claims. (Cl. 137—102)

My invention relates to automation, and includes among its objects and advantages maximum speed in the controlled filling and emptying of a cylinder or the like.

In any comprehensive automation installation, a multitude of tiny chores, such as moving a work piece 6" or 2' to be in position for the next manufacturing operation, or bending over the end of a bit of wire, have to be done automatically to complete the entire cycle of operations. Such minor chores are frequently the limiting factor in the output of a production line, and if any one of them has to be left to hand operation, we have both a high factor of unreliability and an intensely disagreeable chore for the operator who performs the hand operation. Only a semi-moron can continue on such a job and not go crazy.

There are many so called "four-way" valves on the market that can do a very good job in delivering high pressure air quickly to perform the power stroke of a piston and cylinder, but it is usually necessary to use pressures of from three to ten or twenty atmospheres to have an effective energy supply during the power stroke. Assuming passages that are large enough and short enough to accomplish the power stroke within as short a time as other conditions allow, after the power stroke is finished and the return stroke is to be completed, the compressed contents of the cylinder have to get out again and if they pass out through the same passages through which they entered, most of their exit will occur when they occupy from three to ten times the volume that they occupied while going in, and the return stroke is seriously retarded and the entire operation is slowed down.

The bottle neck, therefore, has been for a long time, getting an instrumentality that will let the dense high pressure fluid medium get in as fast as the rest of the apparatus can take it (which is relatively easy); and then getting it out again also with as much speed as the rest of the apparatus can stand, in spite of its greatly increased volume.

In the accompanying drawings:

FIGURE 1 is a side elevation of a valve according to the invention;

FIGURE 2 is a plan view of the shuttle;

FIGURE 3 is a partial section of the shuttle on line 3—3 of FIGURE 2;

FIGURE 4 is a diametrical section of the complete valve with the shuttle in the position it occupies when atmospheric pressure obtains throughout;

FIGURE 5 is the same section with the left half of the shuttle in the position it occupies during the power stroke, and the right half in the position it occupies after the power stroke is completed, which is the same as in FIGURE 4;

FIGURE 6 illustrates on the right hand side a hypothetical configuration that may or may not exist at the inception of the return stroke; and on the left the position during the remainder of the return stroke in full lines, and a hypothetical configuration in dotted lines;

FIGURE 7 is a plan view of an alternative shuttle construction;

FIGURE 8 is a sectional view similar to FIGURE 4 employing the shuttle construction of FIGURE 7, during the power stroke;

FIGURE 9 is a similar section with the right half showing the shuttle position at the beginning of the exhaut stroke and the left hand indicating the position during the main portion of the exhaust stroke.

In the embodiment of the invention selected for illustration in FIGURES 1 to 6 inclusive, the valve has a conventional two part body having a lower portion **10** and an upper portion **12**. These portions have peripherial abutment at **14** and have opposed annular grooves at **16** and **18** defining an annular cavity of substantially rectangular cross section within which the bead **21** of the shuttle, identified as a whole by the reference character **22**, is clamped under firm compression. Upon comparison of FIGURES 3 and 4 is will be noted that the bead **21** has a substantially semi-circular top lobe **24** and a duplicate bottom lobe **26** and when these are confined within the annular groove **16** both lobes are flattened, which compels their curved portions on each side of the flattened area to bulge and almost but not quite fill the groove, leaving tiny clearances at **28** at all four corners of the rectangle.

According to the invention, the shuttle head **30** is a disc of tough, rubbery material, which may, for very severe conditions of service, be reinforced by an inserted disc **32**.

The spaces defined by body portions **10** and **12** include the main annular chamber **34**; a large power port **36** opening radially out of the chamber **34** to deliver fluid to an adjacent cylinder or the like; a large inlet **38** opening downwardly through the top of the chamber and a large outlet **40** opening downwardly through the bottom of the chamber.

The inlet **38** and outlet **40** are co-axial and the outlet **40** is set up into the annular chamber **34** to leave a clearance, indicated at **42**, of axial dimension somewhat less than the axial dimension of the shuttle head **30**.

An operative connection is provided for guiding the movements of the head **30**. The relatively thin annular diaphragm **44** is integral along its inner edge with the outer edge of the head **30** and integral along its outer edge with the inner side of the bead **21**.

The diaphragm **44** is normally so thin that it is incapable of carrying, as a safe working load, the working pressure employed to move the cylinder. Because it is so thin, its endurance under repeated flexure is out of all proportion to an instrumentality having sufficient strutural strength to carry the working load, much as the thin side well of a balloon tire can endure repeated flexure because of its thinness, with a great increase in the life of the tire. To make it possible to have the diaphragm **44** so thin and flexible, I arrange the abutting and guiding services of the metallic parts in such a way that it is impossible for the diaphragm **44** to receive the full working pressure load at any time. In the preferred embodiment the position of rest is that of FIGURE 4 where the head **30** rests on the lip **46** around the exhaust outlet **40**. Best results have been achieved so far with the configuration of the diagram **44** such that, in the position of FIGURE 4, a valve designed to handle up to about 250 p.s.i. will not lift the head **30** off the lip **46** until a differential pressure of about 2 p.s.i. is exerted on the under side of the diaphragm **44**.

In its functioning, the completed structure performs the functions of three check valves. The inlet **38** is opened and closed by the shuttle head **30** to perform the function of a first valve. The outlet **40** is covered and uncovered by the same shuttle head **30** to constitute a third valve; and the diaphragm **44** is provided with twelve large circular orifices **48**. These orifices and the adjacent portions of the diaphragm itself cooperate with the rounded breast **50** of the top casting to constitute a second valve and valve seat. When this second valve is closed, as in FIGURE 4, the annular chamber 34 is subdivided into two separate annular chambers, one above the shuttle and one below. The portion below is always in open communication with the cylinder connection 36.

The twelve large orifices 48, jointly, provide through passage means for pressure fluid coming in at the inlet 38 and passing through the annular chamber to the cylinder connection 36, and their joint effective area is at least equal to or somewhat greater than the effective area of the inlet 38, so that when the initial pressure impulse is delivered, the path of the incoming gas, indicated on the left of FIGURE 5 by the curved arrow 52, is instantly thrown wide open and the maximum theoretical pressure than could ever obtain against the diaphragm 46 will amount to about ⅓ of the pressure coming to the inlet 38. There will be a first pressure drop in the inlet 38 and a second pressure drop across the orifices 48 and a third presure drop across the connection at 36, and at any flow velocity these three drops will be approximately equal.

In actual practice however, this value of ⅓ could only be achieved if the outlet 36 were left open to atmosphere and thus inoperative to perform any useful function. It is not inconceivable that on an arbitrary test under freak conditions, an almost explosive gust of high pressure air at 200 pounds could be delivered suddenly to the inlet 38, with the valve unconnected to any working load, and the orifices 48 would not afford sufficiently rapid exit to prevent the explosion from rupturing the diaphragm 44. However, to accomplish the purpose for which the valve is designed, the outlet 36 has to be connected to a working load and that working load is necessarily an instrumentality defining a receiving chamber that is of minimum volume at the begining of the working stroke. Thus in FIGURE 4 I have indicated, in dotted lines, a conventional cylinder 52 and piston 54 which, in the positions indicated, leave a receiving space at 56 of the same order of magnitude as the chamber 34 itself.

The operation of such a normal combination, when pressure is first received by the inlet 38 is believed to be as follows:

The shuttle head 30 is thrown down into the position of FIGURE 5 by the initial pressure impact on its upper face over the area of the inlet 38. This results in some such position of the parts as that indicated on the right side of FIGURE 5, with the diaphragm 44 still in sealing engagement with the apex of the breast 50. The second movement is the lowering of the diaphragm 44 to the position on the left. This motion will overlap most of the motion of the head 30 down to its seat on the outlet 40. By the time both these movements are completed, enough pressure fluid will have passed into the chamber 34 below the diaphragm and into the space 56 in the cylinder to build up a pressure amounting to a substantial fraction of the inlet pressure. Thus the transitory period of extremely rapid pressure change comes to an end after a time interval that will rarely be as great as one hundredth of a second, and if the piston 54 is blocked in some way and does not yield, the equalization of the pressure on the opposite sides of the diaphragm through the passages 48 will let the entire shuttle resume the rest configuration of FIGURE 4.

However, the withdrawal of the piston 54 during the working stroke will maintain the pressure below the diaphragm 44 enough lower than the pressure above it to keep the diaphragm in the configuration of the left side of FIGURE 5, and a continuous flow indicated by the arrow 52 in FIGURE 5 will continue as long as the movement of the piston continues, after which there will be a pressure equalization and a gentle return to the configuration of FIGURE 4.

If, now, the instrumentality supplying pressure to the inlet 38 is reversed, as suddenly as possible (or gradually, as the case may be), the initial drop of the pressure in the chamber 34 above the diaphragm 44 to a very small differential tending to lift the diaphragm 44 and head 30, will shift the shuttle up substantially instantaneously to the position at the left side of FIGURE 6. Assuming a working pressure of 150 p.s.i., by the time the inlet 38 has its pressure down to 146 p.s.i. the shuttle will be on its way up to the configuration of the left side of FIGURE 6, and the entire contents of the cylinder have a wide open path out through the outlet 40. This large wide open outlet is the sole factor determining the escape of compressed fluid from the cylinder as long as the outflow up through the inlet 38 empties the small upper annular volume at 42 above the diaphragm 44, as fast as the outlet 40 empties the main cylinder. As soon as the rapid discharge through outlet 40 is at an end, the resilience of the parts will cause the shuttle to resume the configuration of FIGURE 4, ready for the next cycle of operation.

It is equally feasible to mold the parts with such a shape that the position of rest, or inactivity, is that indicated on the left side of FIGURE 6 with the shuttle head lightly held against the inlet 38. It is also possible to mold the parts so that the shuttle head 30 will lie in an intermediate position when there are no pressure differences to be equalized. Each of the three unstressed configurations for the shuttle is entirely operative and for certain special installations where some unusual condition is encountered, any of the three configurations may be employed. For general, all around use, I find it preferable to have the position of FIGURE 4 maintained by the resilience of the shuttle itself up to a pressure differential of about 2 p.s.i. Where the piston 54 is not limited in its movement to the left by a crankshaft, this provides a fraction of the cushioning action that is often desired to prevent shock to the parts when movement of the piston 54 to the left comes to an end.

On the right side of FIGURE 6 there is indicated in full lines the position the diaphragm will occupy at the end of the working stroke. As soon as flow as indicated by the arrow 52 ceases, the diaphragm 44 will move into its initial position due to its own resilience, and any reverse flow in the direction indicated by the curved arrow 58 is automatically cut off before it starts.

Depending on the speed with which the pressure in the inlet 38 is lowered, there may be a variety of intermediate positions differing slightly from those illustrated. It is perfectly possible, if the drop in the inlet 38 is extremely rapid, that the diaphragm might be flexed a little, as indicated in dotted lines at 60 on the right in FIGURE 6, and if the rapidity of the drop is sustained until after the shuttle head 30 has seated on the inlet 38, the final condition of the diaphragm might be flexed upward a little as indicated at 62 on the left side of FIGURE 6. I am presently unable to state whether or not any such configurations do exist. But I can state with confidence that if they do, they do not distort the material of the diaphragm beyond what it can safely and easily endure. The sealing engagement between the head 30 and the seat 38 isolates the very small annular volume encircling the head 30 and above the diaphragm 44, and if the diaphragm comes up any further the fluid trapped in that space will rise in pressure and limit the maximum load on the diaphragm. In addition, referring specifically to the left side of FIGURE 6, if the bulge 62 were to extend further in, the distortion of the material radially inward brings the inner edge of the adjacent opening 48 past the peak of the breast 50 and permits a minuscule leakage into the small trapped chamber above the diaphragm, and thus puts an end to the bulge.

It is emphasized that the bulges indicated at 60 and 62 are hypothetical, and I do not know whether they occur or not. However, in actual commercial use, valves according to FIGURES 4, 5, and 6 do function for several millions of cycles without evidence of serious wear, and under a wide variety of speeds and working pressures. For most conditions of service I prefer to reinforce the mechanical strength of the head 30 by having the exhaust port 40 sub-divided by four radial arms 64 into pie-shaped quadrants. This permits shuttles without a reinforcing disc 32 to operate effectively up to materially higher intermediate pressures, and extends the peak pressure that can be borne by shuttles in which the reinforcement 32 is present.

It will be obvious that in any installation of automation the size of the instrumentality to be controlled by such a valve may vary, on a volume basis by 100 to 1 or even 500 to 1. Also the time cycle may be very slow or very fast, and the preferred air supply for the system as a whole may be anything from 25 p.s.i. to 300 p.s.i.

In FIGURES 7, 8 and 9 I have indicated a modification in which there is a double seal for the second valve. It is believed that extended practical service experience may indicate that this modification has certain advantages in connection with very low working pressures and slow time cycles and large volumes of motive fluid.

The lower body portion 10 may be identical with that in FIGURE 4, but the upper body portion 66 has a differently shaped lower face. The main shuttle member 68 is connected to the annular diaphragm 70 substantially at its upper edge. The diaphragm has twelve apertures 72 corresponding to the apertures 48 in FIGURE 4, but in the normal, unstressed condition of rest, indicated in the left half of FIGURE 9, the head 68 bears against a plane shoulder at 74. The diaphragm 70 curves downwardly and then outwardly over a narrow breast at 76 and then outwardly in abutment with a plane annulus 78 generally similar to that of the embodiment of FIGURE 4.

A second annular valve member of flexible material is provided, which has twelve flaps 80 each extending radially and, in undistorted condition, closing the lower end of one of the twelve openings 72. The outer periphery of the diaphragm 70 carries a smaller bead 82 and the second valve member has a companion bead 84. There is a narrow tongue and groove interlocking connection between the beads 82 and 84, indicated at 86. Except along their interlocking faces at 86, both beads 82 and 84 have the cross section of a rounded Maltese cross, with lobes at each corner separated by small grooves to leave a little clearance so that there will be repeated line contact but no volumetric compression of the beads.

Starting from the rest position indicated at the left side of FIGURE 9 the impact of the pressure in the inlet 88 throws the head 68 down against the outlet 40. Movement of the head 68 down to the lower position indicated on the right in FIGURE 9 would distort the parts to the configuration there illustrated, with the diaphragm 70 bent up into a downwardly opening groove. However, this condition probably does not exist, even instantaneously, because by the time the head 68 is half way down, the influx is sufficient to blow the diaphragm 70 down to the position of FIGURE 8 and to flex all the tabs 80 into the open position of FIGURE 8 so that all twelve of the openings 72 are wide open for flow into the lower part of the annular chamber 90 and out through the cylinder connection at 36.

While the flow at 36 continues throughout the power stroke, the parts remain in the configuration of FIGURE 8 but the mere cessation of flow through the connection at 36 will let all the flaps 80 rise into sealing engagement with the lower ends of the openings 72. The flaps 80 could never cover these openings and withstand any such pressure as the working line pressure, but they are never subjected to any such pressure. After the flaps 80 have closed because there is no flow to hold them open, reduction in the pressure in the inlet 88 will snap the main shuttle back through the intermediate position on the right of FIGURE 9 and up to the position of rest on the left of FIGURE 9, with the chamber 90 vented to atmosphere to the outlet 40. During the initial stages of the emptying of the instrumentality filled by the passage 36, pressures up to only a little less than the full line pressure may be exerted against the shuttle while in the configuration shown on the left in FIGURE 9, but this pressure is effective only on the head 68 and the openings at 72 are closed at both ends. Their upper ends rest against solid metal and the flaps 80 cover their lower ends.

In this embodiment there is practically no radial stretching of the material in the zone where the openings 72 are located and the diaphragm 70 moves substantially axially from the position of FIGURE 8 to that on the left of FIGURE 9 and back again. The trough-like configuration at the right of FIGURE 9 is much more likely to occur at the beginning of the exhaust stroke than at the beginning of the power stroke, but whether or not it happens in either or both movements is immaterial.

To facilitate correct assembly of the lower wing, I provide a boss 92 projecting downward from the shuttle and entered between two of the adjacent flaps 80 so that all the flaps register with the holes 72.

Others may readily adapt the invention for use under various conditions of service by employing one or more of the novel features disclosed or equivalents thereof. As at present advised, with respect to the apparent scope of my invention, I desire to claim the following subject matter:

1. In a high-speed, quick release valve, in combination: A unitary valve member of flexible material; said valve member having a peripheral bead and a central plug, and an intermediate relatively thin annulus; said intermediate annulus being united integrally along its outer edge to said bead, and along its inner edge to said plug; a housing comprising, an inlet cup opening in one direction and an outlet and discharge cup opening in the other direction; said cups having peripheral lips presenting abutment faces to each other; said cups immediately inside said abutment faces, having annular grooves opening toward each other; said grooves jointly defining an annular space fitting and gripping said bead tightly; opposed inlet and discharge passages in said cups; said passages being coaxial with said cups and diaphragm; said plug having substantially smooth abutment faces at its axial extremities near its outer edge; said passages having smooth annular abutment seats positioned to receive the adjacent faces of said plug; said inlet cup being relatively shallow and having an inwardly bulging breast immediately inside its lip; said outlet and discharge cup having a relatively deep annular groove extending axially outside said discharge passage away from the other cup; said outlet and discharge cup having a lateral outlet passage communicating with said deep annular groove, and adapted to be connected to a power cylinder or the like; said annulus having a multiplicity of openings intermediate its inner and outer edges; said apertures being positioned to lie in the annular portion hugging said breast when there is pressure below said annulus in excess of that above the annulus, and said annulus and plug have been moved up into discharge position with said plug in abutment with said inlet passage; whereby said apertures are closed by said breast and a wide open communication is established between said outlet passage and said exhaust passage; said apertures lying out in said deep annular groove when there is pressure above said plug and annulus in excess of that below and said plug is in abutment with said discharge passage; whereby, when said outlet passage is connected to a power cylinder or the like, only relatively light pressure differences can be developed during the power stroke; said inlet cup being shaped to cushion all said annulus and plug, except for the central axial inlet passage, without distorting said annulus beyond its elastic limit, during the initial portion of the return stroke when the fluid pressure below said valve member is at or near maximum load.

2. A combination according to claim 1 in which a second bead is housed in the same groove with said first

mentioned bead; said second bead having a thin resilient leaf projecting radially inward adjacent each orifice only far enough to cover and seal the end of said orifice remote from said breast.

3. A combination according to claim 1 in which the clearances and proportions of the parts are such that, during exhaust, the effective flow areas for fluid flow, first, into said annular groove from said lateral outlet passage, second, from said groove into said discharge passage, and third, out through said discharge passage, are approximately equal and the maximum available within the geometrical confines of the structure.

4. A combination according to claim 1 in which said annulus, in undistorted condition, is of greater radial dimension than the space between the outer edge of said plug and the inner edge of said bead, whereby the annulus bellies either up or down when not under fluid pressure.

5. A combination according to claim 1, in which said seats have plane faces situated in planes parallel to the transverse plane of said lip abutments, said planes being axially offset in opposite directions on opposite sides of the lip abutment plane, to leave a predetermined axial clearance above or below said plug, said clearance being less than the axial dimension of said plug.

6. A combination according to claim 5 in which said valve member, in unassembled and undistorted shape, is not symmetrical about any transverse plane and requires assembly in one axial orientation only; said plug having a small central button on the face exposed to the fingers of the assembler when laid in place on the outlet and discharge cup.

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