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VALVE CONTROL FOR VIBRATOR AND LIKE APPARATUS OPERATING ON ELASTIC FLUID

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FIG. 2

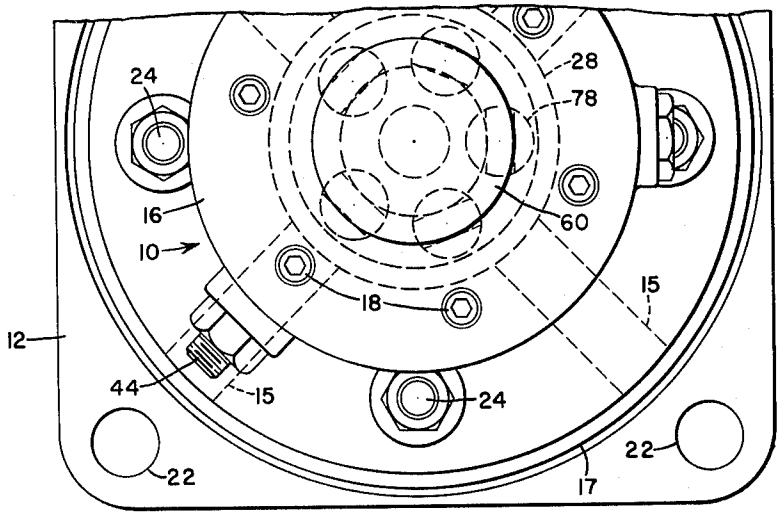


FIG. 3

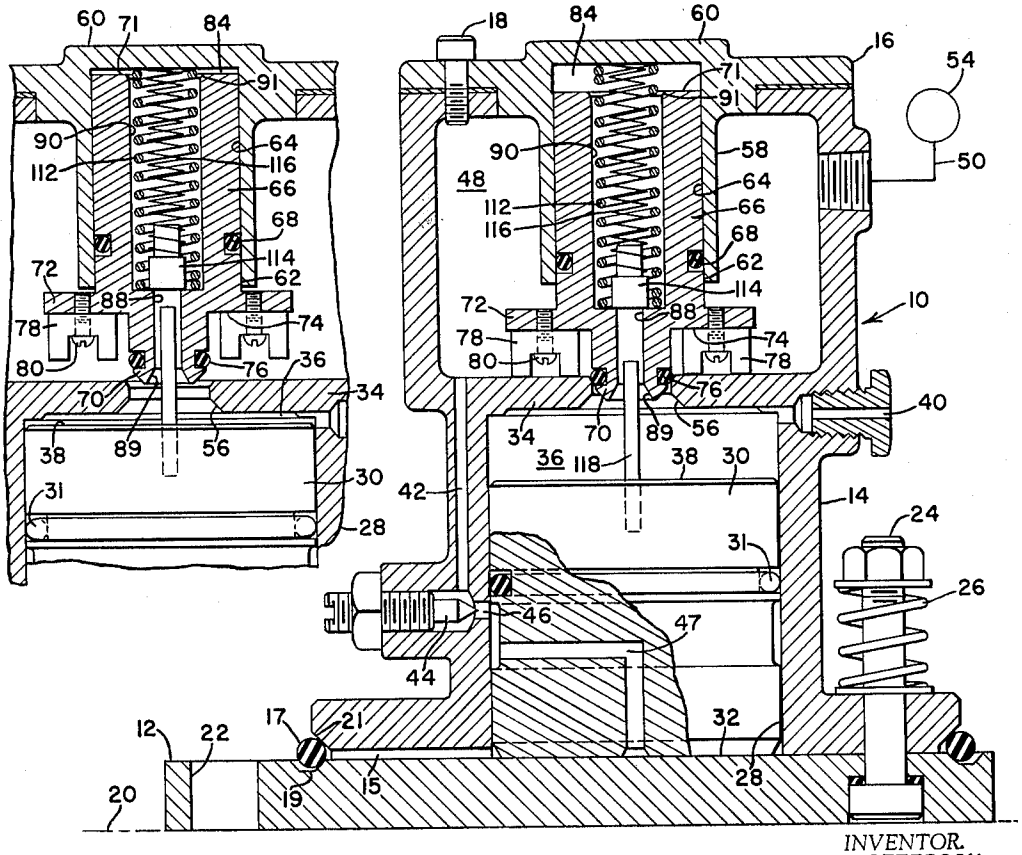


FIG. 1

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VALVE CONTROL FOR VIBRATOR AND LIKE APPARATUS OPERATING ON ELASTIC FLUID

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This invention relates to a force-applying apparatus and more particularly to that type of apparatus in which the force is derived from elastic fluid such as compressed air and is converted to mechanical forces for use in mechanisms employed for vibrating, shaking, pounding, punching, impacting etc. More particularly, the invention relates to improvements in devices for regulating the admission of elastic fluid pressure in "explosive bursts" as distinguished from virtually non-compressible fluids such as oil, etc.

Exemplary of this general type of apparatus is that forming the subject matter of co-pending application Serial No. 318,638, filed October 24, 1963, in which a hammer or weight is carried in a cage or equivalent support for reciprocation toward and away from, for example, a plate which may be attached to an object to be vibrated, such as a load-carrying container in which the vibratory forces imparted to the container facilitate unloading. In the absence of the striker plate, the cage or hammer support may be attached directly to such container or other object, or the hammer or weight may be used for punching, pile driving etc. In still other instances, the hammer need not strike the striker plate or its equivalent but the reciprocatory motion developed may be utilized without the impact. In the example referred to, the hammer cage is divided or separated from an inlet chamber by a partition having an opening therein with which a valve cooperates for the intermittent admission of air to piston means associated with the hammer and operating in an expansive or power chamber. Each time air or equivalent fluid pressure is introduced to the piston means, the hammer moves away from the partition on what may be regarded as a power stroke. Depending upon the position and location of the apparatus, the hammer has a return stroke on which it is biased, either by its own weight or by other biasing means. The arrangement in the application referred to is such that the control valve and hammer are mechanically independent of each other, and the means for influencing the valve to open and close includes passage means, vent means and control of the latter so that as the hammer moves on its power and return strokes, the valve automatically opens and closes.

It is a principal object of the present invention to provide an improved valve system and control therefor. The improved system features conditioning of the valve for reopening by a counter-acting valve chamber and means for trapping and releasing pressure as respects this chamber, the latter phase being dependent on hammer position. Nevertheless, the main valve itself is not engaged by the hammer, as is the case in still earlier structures. More specifically, it is an object to time hammer and valve movement so that the full stroke of the hammer may be utilized, which is especially important at relatively higher speeds. At lower speeds, the hammer normally returns a full stroke and "waits" for the valve to open, in the prior application, but at higher speeds the valve is apt to open prematurely and thus move the hammer back on its power stroke.

A still further object of the invention resides in a construction in which the valve structure and control therefor may be readily incorporated in a unit that is easily installed and removed from the basic supporting structure.

It is a further object of the invention to exploit these principles in a commercially successful device capable of developing relatively high forces, viz., in the range of twenty to thirty-five foot pounds on as little as 40 p.s.i. Such apparatus, using air at as low as one-half to five cubic feet per minute, may be operated by a fractional horsepower compressor.

A further object is to incorporate in such apparatus the characteristics of strength, ruggedness and portability; e.g., in weight ranges of from 25–100 lbs. so that it may be easily handled by one man as it is moved from job to job.

The foregoing and other important objects and desirable features inherent in and encompassed by the invention will become apparent as preferred embodiments thereof are disclosed in detail in the ensuing description and accompanying sheets of drawings, the figures of which are described below.

FIGURE 1 is a sectional view, with portions in section contained in two planes intersecting at the axis of the apparatus, with a source of fluid pressure and associated lines shown schematically.

FIGURE 2 is a fragmentary plan view.

FIGURE 3 is a fragmentary sectional view of a center portion of FIGURE 1, showing the valve in its open position.

The vibrator as a whole may be regarded, by way of example, as comprising a unitary casing structure 10 made up of coaxial parts 12, 14 and 16, the latter being a cover rigidly but removably joined to the part 14 by a circle of cap screws 18. In the illustrated use-environment, the unit is mounted on a typical object to be vibrated (represented at 20) and hence part 12 is lowermost; but, as will be clear from what ensues herein, this position does not exclude others. The unit may be removably attached to such object by providing the part 12 as an attaching flange having bolt-receiving openings 22. Parts 12 and 14 are joined together by a circle of bolts 24 including cushion springs 26.

Part 14, which may be a casting, forms a hammer cage or support 28 within which a hammer or its equivalent mass 30 is reciprocable on alternate strokes (here vertical) between upper and lower limits such as, respectively, the top surface 32 of part 12 and the under surface of a partition 34 between upper and lower portions of the part 14. That portion of cage 28 between hammer 30 and partition 34 establishes a power cylinder or expansive chamber 36, shown expanded in FIG. 1 because the hammer is down but capable of contraction as the hammer moves up (FIG. 3). The top end of the hammer is thus a movable wall or piston means 38 acting on or in conjunction with the hammer. The top end of chamber 36 is vented at 40 to enable discharge thereof on the up or return stroke of the hammer. The bottom end of the cage 28 is constructed to avoid trapping of air below the hammer as the hammer, having a suitable seal 31 with the interior wall or cylinder of the cage, reciprocates during operation. The under surface of part 14 has radial grooves 15 which are normally closed at their outer ends by an O-ring 17 seated in a matched annular groove 19 and a chamfer 21 respectively in parts 12 and 14. This ring can yield to allow trapped air to escape.

As the hammer moves upward from the position of FIG. 1, air is discharged from the chamber 36 through the vent 40, which is large enough for this purpose but small enough to avoid wasting air on the power stroke of the hammer. If the unit were inverted (as it might well be) the hammer would return by gravity. But in its present posture, some other biasing means must be relied on. That selected is a pressure means, including a fluid passage 42 controlled by a needle valve 44 and orifice 46

which leads via an L-shaped passage 47 to the bottom of the hammer. For the present, let it be assumed that passage 42 is connected to a source of elastic fluid under pressure, such as compressed air. Regulation of the needle valve 44 controls the rate of return movement of the hammer, it being understood that the tension in the O-ring 17 is sufficient to prevent leakage from the slots 15 at this time. More will be said below about the illustrated connection of the passage 42 to a pressure source.

The partition 34 separates the power chamber 36 from an upper or inlet chamber 48 which is constantly pressurized by an inlet line 50 connected to a source of elastic fluid (e.g., compressed air) such as a compressor, shown schematically at 54, or to a compressed air line (not shown) such as are available—generally at 100 p.s.i.—in most industrial plants, etc. If desired, line 50 may have a conventional pressure regulator valve which allows the air to flow into the chamber 48 at a rate determined by the valve's capacity, the flow stopping when inlet chamber pressure reaches a predetermined pressure (the pre-set maximum of the regulator valve).

Transmission of fluid pressure from inlet chamber 48 to power chamber 36, and control thereof, is achieved by means including the partition 34 and a port 56 therein, shown here as circular and centrally located, by way of example. Broadly the "geography" of the port and its allied components could be otherwise than as shown.

The central underside of cover 16 has within inlet chamber 48 an integral depending valve support 58 having a closed upper end 60 and an open lower end 62, which is the bottom of a valve bore 64 which carries a main valve 66 equipped with a suitable seal 68. The valve 66 is coaxial with port 56 and has a lower port-control end 70 and a top end 71 exposed to the closed end 60 of the valve bore and forming therewith a valve chamber 84. The valve 66 further has, intermediate the cylindrical port-control portion 70 and the bottom end 62 of support 58, an enlarged annular flange 72. The lesser diameter of portion 70 as respects the main body of the valve affords a first pressure-receivable area 74 (the larger diameter of flange 72 is immaterial, since both faces of the flange are exposed to inlet chamber 48). The diameter of portion 70 and the amount of axial movement of the valve are such that said portion slightly enters the port in the port-closing position of the valve (FIG. 1) and is withdrawn from the port in the port-opening position of the valve (FIG. 3). This portion 70 is supplemented by an annular seal 76, here a conventional O-ring, to perfect closing of the port without expensive lapping of metal surfaces.

Magnetic means, here a circle of separate magnets 78 mounted on the underside of flange 72 by screws 80, attracts the valve 66 to its closed position via metallic partition 34. This attractive force is somewhat less than the force on area 74 at predetermined minimum pressure expressed in pounds per square inch in inlet chamber 48 when valve chamber 84 is at atmosphere. Thus, when the valve is closed (FIG. 1) and held there by the magnetic means, the effects of chamber pressure on area 74 will have to exceed the magnetic force, plus other forces to be noted later, in order to open the valve (FIG. 3). This can be termed the pre-set value. In other words, the value the pre-set inlet chamber pressure has in overcoming the magnet hold with a given area at 74. These forces can be readily calculated for devices of different sizes, capacities and rates of operation, and to be taken into account are such things as frictional drag of O-ring seal 76, friction between valve 66 and valve bore 64 and frictional drag of the seal 68, here also an O-ring, between the valve and the bore, besides strength of magnets, etc. The word "rise" as used herein is, of course, relative, for the inlet chamber pressure can increase relative to valve chamber pressure if the latter drops. Actually, it is the pressure differential that opens the valve.

Seal 68 operates as means isolating the valve chamber 84 from inlet chamber 48 when valve 66 is closed. In short, when the valve closes port 56, both power chamber 36 and valve chamber 84 are cut off from inlet chamber pressure, the rise of which becomes effective, when the magnetic force is overcome, to open the valve, allowing a rush of air through the port and into power chamber 36 to force the piston and hammer downwardly or away from partition 34, which phase of operation is not retarded by discharge passage 40.

Now, with the hammer down and valve 66 open via inlet chamber pressure acting on pressure area 74, it remains to reclose the valve to cut off air to the power chamber so that the piston-hammer may return as power chamber air is discharged via vent 40. To accomplish this requires that some means be provided to return the valve automatically to closed position; that is, without, for example, cutting off line 50.

This is achieved, by counteracting at least part of the valve-opening force by an opposing force so as to effectuate the magnets as an ultimate valve-closing means. Briefly, what is done is to provide passage means to lead inlet chamber pressure to valve chamber 84 where it will act on the second pressure-receiving area provided by top end 71 of valve 66, which is opposed to the first area 74. It will be appreciated that when valve 66 is open, the whole lower end thereof is then acted on by inlet chamber pressure; and in effect the whole upper end 71 is exposed to valve chamber 84.

The passage means here is an axial through passage 88 in valve 66 opening at 89 at valve end 70 and made up of a series of counterbores including a relatively large bore 90 which opens at 91 to valve chamber 84. This passage is normally effective as a charging passage only when valve 66 is open, for when the valve is closed (FIG. 1), the lower end 89 of the passage opens to the power chamber and, being cut off from the inlet chamber 48, serves then, when properly controlled, as a discharging passage. Also, some means must be provided to absorb the momentum of the opening valve so that it will not destroy itself against the bottom end of valve support 58. Such cushion means may also be used to return the valve to the influence of the closing means comprising the magnets 78.

Typical cushion means may include a coaxial coiled spring 112 loosely carried in valve bore 90 and acting between the valve 66 and the closed end 60 of valve support 58. Although, in the posture of the unit shown here, gravity would serve to bring the valve 66 back to the "reach" of magnets 78, spring 112 has practical advantages in supplementing the magnetic means, such as overcoming the "break away" resistance of the O-ring 68, enabling the use of magnets of smaller force, and, as stated, serving as a cushion against extreme valve-opening movement.

Control of the passage 88 as respects trapping and releasing fluid pressure in and from chamber 84 is achieved by check valve 114, normally closing passage 88 at the shoulder formed by the junction of that passage with valve bore 90 and biased to closed position by a relatively light coil spring 116 disposed loosely within valve spring 112 and acting between the check valve and the closed end of valve housing 58. In addition, means is provided for timing positive opening of the check valve with hammer position on the return stroke. A representative means is shown here as a rod 118 carried by the hammer and having its free upper end projecting into the open bottom end 89 of passage 88 so as to engage and unseat the check valve 114 in a predetermined position on the hammer return stroke. Obviously, a reversal of parts is available here.

The starting positions of the parts before pressure is applied from line 50, can be those shown in FIG. 1. Line pressure when applied via 54–50 builds up in inlet chamber 48 and before it reaches its pre-set minimum; e.g., 30 p.s.i., while valve 66 is closed, it acts via passage 42–46–47, here connected to inlet chamber 48, to move hammer 30 to its up position, rod 118 opening check

valve 114. Valve chamber 84 is therefore open to atmosphere via 86–36–40. Continued pressure rise in inlet chamber 48 acts against pressure area 74 on valve 66 until it overcomes the attractive or holding force of magnets 78 which is, say, eighteen pounds as against a pressure area at 74 of, say, .600 square inch, in which case the valve will quickly open at 30 p.s.i. in the inlet chamber, or approximately so because of frictional drag and other small variables. The rapidity of valve opening occurs because, as the magnets break away from partition 34, the magnetic attraction deteriorates.

When valve 66 opens, inlet chamber pressure rushes into power chamber 36, acting much as an explosive burst on piston 38 to drive hammer 30 downwardly. Whether or not the hammer strikes surface 32, a relatively powerful impulse will result, jarring the object or applying other desired force to an equivalent object. As stated above, discharge passage 40 is so restricted relative to the charge of air bursting into power chamber 36 as to have no material effect thereon. If desired, adjustment of this passage could be provided as another means besides needle valve 44 to vary the rate of return of the hammer. It is preferred that the hammer should reach or substantially reach its return limit (partition 34) before valve 66 re-opens after closing following its opening action just described.

Valve 66 closes because of force developed in valve chamber 84 to counteract the valve opening force, which will be clear by recognizing that when valve 66 opens it exposes its lower end 70, and thus its passage 88, to inlet chamber pressure which easily opens check valve 114 and enters valve chamber 84 to act against valve area 72, and the check valve closes as, ultimately, substantially balancing forces occur against both ends of the valve at inlet chamber pressure. The valve is then conditioned to again come under the attractive influence of the magnets. The expression "substantially balancing" is used here as one of convenience, because exactly equal forces need and may not occur at opposite ends of the valve. For example, the attractive force of the magnets could take effect prior to exact equalization. Also, when valve 66 opens port 56, there will be a pressure drop in the inlet chamber continuing as the power chamber expands with the pressure trapped in the valve chamber 84 resulting in a pressure differential in favor of valve closing. Factors such as this reveal convenient measures for varying the speed of valve closing by varying the rate or time of "equalization," as by judiciously proportioning the diameter of passage 88.

In this instance, the magnets are assisted by the springs 112 and 116; although, it will be clear that stronger magnets could eliminate the spring 112 (the spring 116 has negligible force in this phase) so far as forces are concerned. Stronger magnets will enable greater valve opening, since their power of attraction is greater and they will have greater "reach" for the valve. The spring 112, however, has at least the three distinct advantages pointed out earlier. If desired, spring 112 could be adjusted.

Now, with valve 66 closed, there again occurs the isolation of chambers 48, 36 and 84 from one another. Air let into chamber 84 when the valve opens becomes trapped and unless released would prevent re-opening of the valve, since area 72 would effectively oppose area 74 and the magnetic force could not be overcome. According to the present invention, the check valve 114 is positively opened because it is unseated by the rod or element 118 as the hammer reaches the end of its return stroke. This releases the trapped pressure via 89–36–40 and restores the valve area differential required to escape the magnets or holding means. It will be clear that the length of rod 118 can be varied to change the time of opening of check valve 114. It should be observed that higher pressures can be introduced into the inlet chamber 48, via the line 50, than the preset minimum and the intervals can be controlled by dropping the pressure in valve chamber 84 without returning it to atmosphere, for it is the relation of inlet to valve chamber pressure that allows the valve to open and not necessarily the relation to atmosphere. Another significant advantage of the present construction is that the space between the bottom of the hammer and the top of the part 12 is always under pressure, even on the bias stroke, and, therefore, dust etc. is not "inhaled" into the bottom of the hammer cage.

Features and advantages, other than those categorically enumerated, will readily occur to those versed in the art, as will many modifications and alterations in the preferred embodiments disclosed, all of which may be achieved without departure from the spirit and scope of the invention.

What is claimed is:

1. Vibrator apparatus, comprising: means including a pressure-chargeable and dischargeable power chamber having a hammer and piston means movable in one direction upon charging of said chamber and biased for return movement upon discharge of said chamber; means including an inlet chamber connectible to a source of elastic fluid under pressure; means including a chamber-connecting port, a main valve for opening and closing the port, and a valve support movably carrying said valve; valve-holding means releasably holding the valve closed; means including a pressure-chargeable and dischargeable valve chamber operatively related to a first pressure area exposed to said valve chamber for acting in a closing direction on said main valve when said valve chamber is charged; means including a second pressure area acting on the main valve and exposed to inlet chamber pressure and effective upon a predetermined pressure differential between the valve chamber and inlet chamber in favor of said second area to overcome the holding means for opening said main valve; and means for regulating the occurrence of said pressure differential including a passage leading at one end to the valve chamber and alternately connectible at its other end to inlet chamber pressure when the main valve is open and to a lower pressure when said main valve is closed so as to respectively charge and discharge said valve chamber, a secondary valve in the passage yieldable to open to inlet chamber pressure when the main valve opens, whereby to charge said valve chamber with inlet chamber pressure so as to cause re-closing of the main valve, said secondary valve being arranged to close said passage incident to charging said valve chamber so as to trap pressure in said valve chamber at a value sufficient to prevent inlet chamber pressure on said second main-valve area from immediately re-opening said main valve, and means operative by the hammer and piston means upon predetermined return movement thereof to forcibly open said secondary valve to release said trapped pressure for discharging the valve chamber and thereby to incur said predetermined pressure differential in favor of said second area.

2. The invention defined in claim 1, including: casing structure carrying the power and inlet chambers and having a partition separating the chamber, said port being provided in said partition and said valve support being disposed in the inlet chamber, said main valve having a port-closing portion exposed via the port to the power chamber, said passage having an open end at said port-closing portion of the valve exposed to the power chamber when the main valve is closed and to the inlet chamber when the main valve is open, and the means operative to forcibly open the secondary valve includes an element extending through said open end of the passage means between the secondary valve and the hammer and piston means.

3. The invention defined in claim 2, in which: the passage extends through the valve from said open end to said valve chamber.

4. The invention defined in claim 3, in which: the secondary valve is a check valve in the passage biased by

a closing spring between said check valve and the valve support.

5. The invention defined in claim 1, in which: the means for forcibly opening the secondary valve includes an element connected to the hammer and piston means and extending into the passage means for engagement with the secondary valve.

6. The invention defined in claim 1, including: resilient means acting on the main valve for absorbing the momentum of the opening main valve and for urging the valve back to the valve-holding means.

7. The invention defined in claim 1, in which: the released pressure from the valve chamber is directed to the power chamber for discharge as the power chamber discharges.

8. The invention defined in claim 7, in which: the rate of discharge of the power chamber is adjustable.

9. The invention defined in claim 1, in which: the biased return of the hammer and piston means includes a connection to a source of elastic fluid under pressure.

10. The invention defined in claim 1, in which: the biased return of the hammer and piston means includes a fluid connection to the inlet chamber of such capacity as to carry insufficient pressure in opposition to movement of the hammer and piston means in said one direction when the port is open while carrying sufficient pressure to return the hammer and piston means when the port is closed.

11. The invention defined in claim 1, in which: the valve-holding means include magnetic means attracting the main valve to closed position.

12. Vibrator apparatus, comprising: means including a pressure chargeable and dischargeable power chamber having a hammer and piston means movable in one direction upon charging of said chamber and in the opposite direction upon discharge of said chamber; means including an inlet chamber connectible to a source of elastic fluid under pressure; means including a chamber-connecting port and a main valve for opening and closing the port; valve-holding means releasably holding the valve closed; means including pressure-chargeable valve chamber and a first pressure area acting on the valve and exposed to said valve chamber for returning said main valve to said valve-holding means when said valve chamber is charged; means including a second pressure area acting on the valve exposed to inlet chamber pressure and effective upon a predetermined pressure differential between said areas in favor of said second area to overcome the holding means for opening said valve; and means for regulating the occurrence of said pressure differential, including a passage leading at one end to the valve chamber and at its other end to the inlet chamber and alternately to a pressure lower than inlet chamber pressure, passage control means operative to allow fluid pressure flow from the inlet to the valve chambers upon opening of the valve, to close said passage following opening of the valve so as to trap fluid pressure in the valve chamber and thereby to prevent immediate re-opening of the valve following closing thereof, and said passage control means being further operative to open said valve chamber to a lower pressure upon return of the hammer to a predetermined position on its return movement whereby to release fluid pressure trapped in said valve chamber.

13. The invention defined in claim 12, wherein said passage control means includes an element positively engageable with the hammer upon return movement thereof to effect connection of the valve chamber to said lower pressure.

14. The invention defined in claim 12, in which: the valve-holding means includes magnetic means releasably holding the valve closed and supplementing the valve-return action of said first pressure area.

15. The invention defined in claim 12, in which: a seal is provided by an O-ring between the valve and the valve support.

16. The invention defined in claim 12, in which: spring means is provided to act on the valve for storing at least part of the valve-opening momentum releasable as a valve-closing reaction.

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SAMUEL LEVINE, *Primary Examiner.*