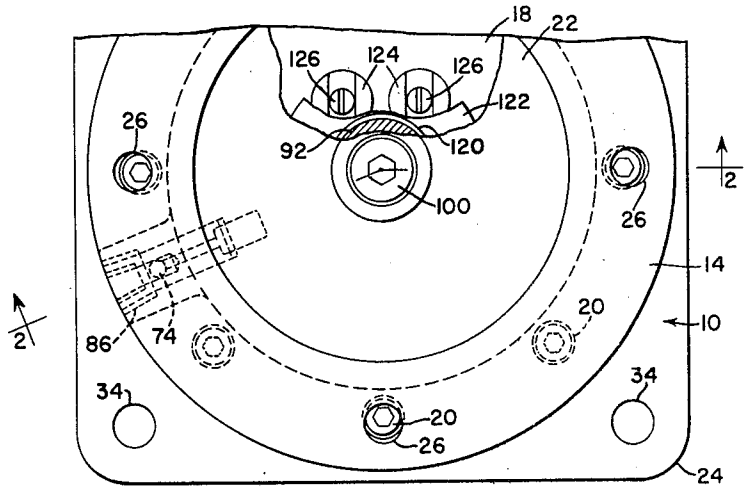
Nov. 9, 1965 A. H. PETERSON 3,216,329

FORCE-APPLYING APPARATUS

Original Filed March 5, 1962 2 Sheets-Sheet 1

FIG. 1



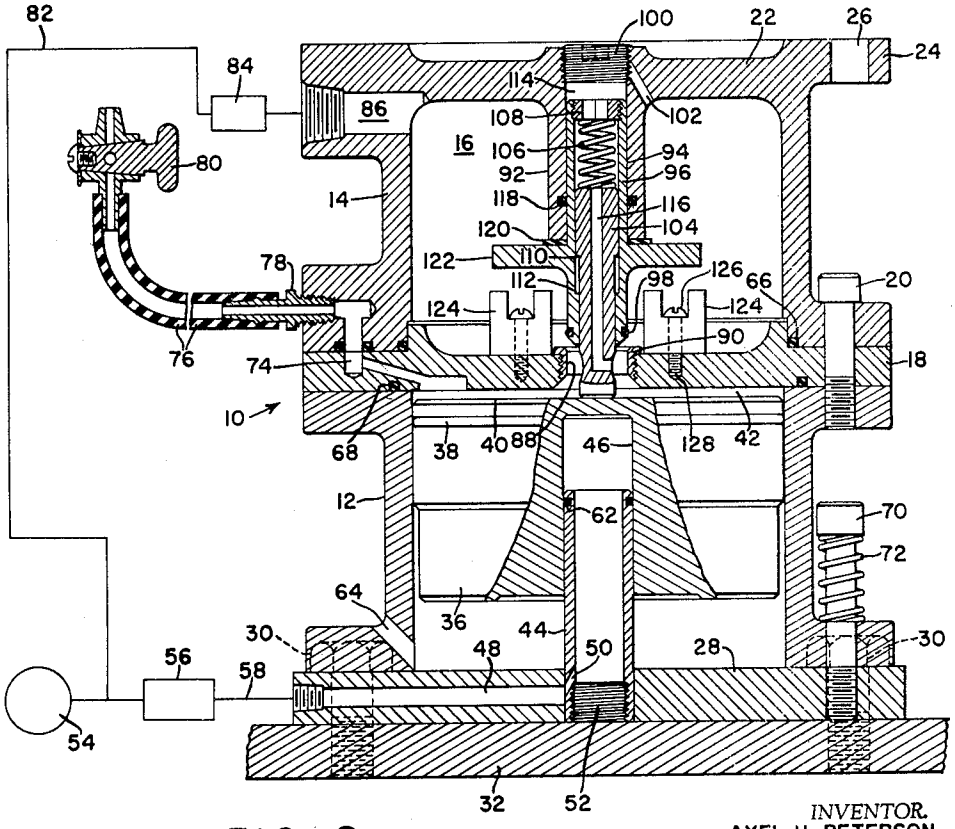


FIG. 2

INVENTOR.
AXEL H. PETERSON

BY

ATTORNEY

Nov. 9, 1965 A. H. PETERSON 3,216,329

FORCE-APPLYING APPARATUS

Original Filed March 5, 1962 2 Sheets-Sheet 2

FIG. 3

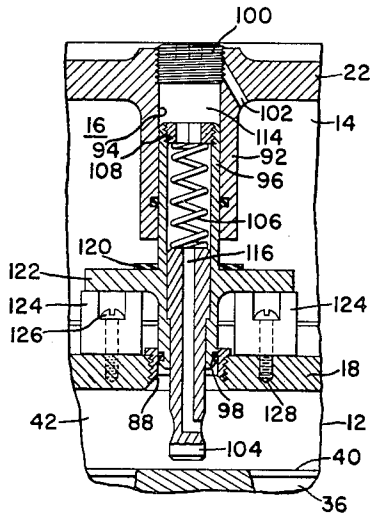


FIG. 4

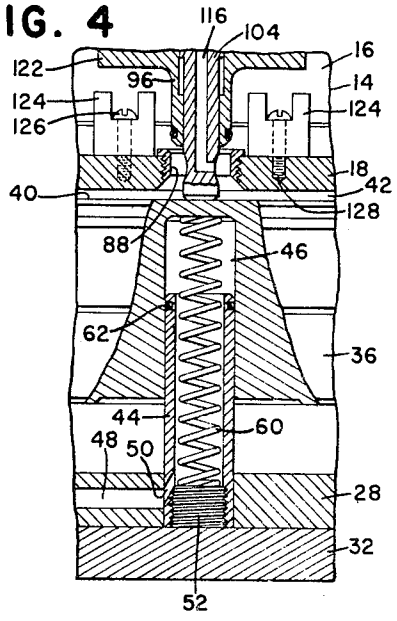
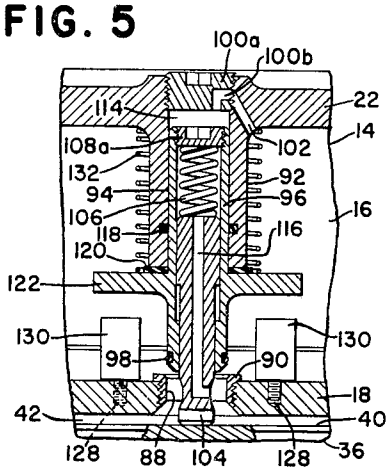


FIG. 5



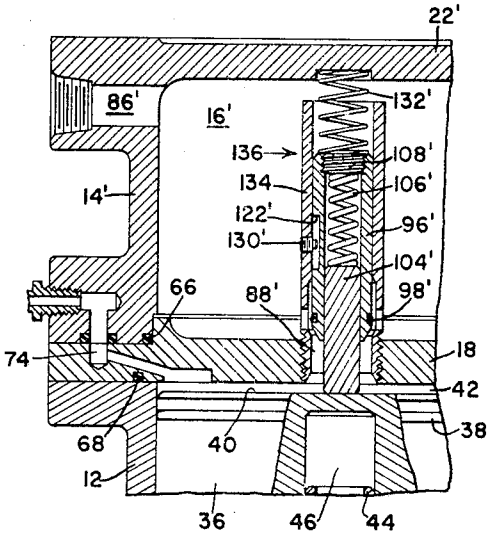


FIG. 6

INVENTOR.
AXEL H. PETERSON

BY

ATTORNEY

United States Patent Office 3,216,329 Patented Nov. 9, 1965

3,216,329

FORCE-APPLYING APPARATUS

Axel H. Peterson, 4431 5th Ave., Rock Island, Ill.

Continuation of application Ser. No. 177,949, Mar. 5, 1962. This application Oct. 23, 1964, Ser. No. 405,953
30 Claims. (Cl. 91—52)

This application is a continuation of copending application Ser. No. 177,949, filed March 5, 1962 (now abandoned) and the invention relates to a force-applying apparatus and more particularly to that type of apparatus in which the force is derived from pneumatic or like means and is converted to mechanical forces for use in mechanisms employed for vibrating, shaking, pounding, punching, impacting etc.

Exemplary of this general type of apparatus is that forming the subject matter of copending application Ser. No. 146,859, filed October 23, 1961, in which energy-conversion means such as a hammer or weight is carried in a cage or equivalent support for reciprocation toward and away from a plate which, in one example, may be attached to an object to be vibrated, such as a load-carrying container in which the vibratory forces imparted to the container facilitates unloading. In the absence of the striker plate, the cage or hammer support may be attached directly to such car 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 substitute therefor 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 or accumulator chamber by a partition having an opening or port therein with which a valve cooperates for the intermittent admission of air to a power chamber having piston means associated with the hammer. Each time air or equivalent fluid pressure is introduced to the piston means, the hammer moves 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 is such that the hammer on its return stroke opens the valve to admit another charge of pressure to the piston. As the hammer moves on its power stroke, the valve automatically closes, and other discharge means are provided for discharging the piston so that the hammer may return.

Since, in the prior apparatus just referred to, operation of the valve is directly dependent upon the return of the hammer, relatively high speeds are obtainable, roughly in the order of, say, two thousand to ten thousand vibrations per minute. According to the present invention, much lower speeds are obtainable by modified control means for the valve.

It is therefore a principal object of the present invention to provide improved control means for the valve in apparatus of the character described. The improved control means features valve-opening means capable of accumulating or storing energy in such fashion that when the hammer attains a predetermined position in its return stroke, the accumulated energy is expended as a force which opens the valve rapidly and widely, thus avoiding "cracking" or "creeping" of the valve as in the prior apparatus. It is a significant object of the present invention to utilize in the control means the application of pressure to pressure-receivable areas so related as to develop pressure-responsive valve-return means. A further object utilizes in the control means releasable elements which retain the valve in its closed position until the force developed in the opening means is sufficient to overcome the closing force. Specifically, it is a feature of

the invention to use magnetic elements for applying at least part of the valve-closing forces.

A still further object of the invention resides in a construction in which the apparatus may be converted from the type in which the valve-closing force is pressure-responsive to one in which the valve-closing force is developed at least in part by magnetic elements. A still further object is the provision of a design 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. Another object is to utilize fluid biasing means providing a fluid cushion for the hammer on its power stroke, which cushion functions also to cause the hammer to move on its return stroke. Still another object is the provision of remote-control means for exhausting the cylinder and piston means which develops the power stroke for the piston. Another object resides in the cushioning means involved in the attachment of the apparatus to an object to receive forces therefrom.

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 plan view, with portions broken away and other portions shown in section, of one form of the apparatus.

FIGURE 2 is a section as seen generally on the line 2—2 of FIGURE 1, with a source of fluid pressure and associated lines shown schematically.

FIGURE 3 is a fragmentary sectional view of a center portion of FIGURE 2, showing the valve in its closed position.

FIGURE 4 is a section similar to the central portion of FIGURE 2 but showing a different form of means for biasing the hammer on its return stroke.

FIGURE 5 is a view also similar to the central portion of FIGURE 2 but showing a modified construction in which a different form of means is provided for applying the valve closing force.

FIGURE 6 is a fragmentary sectional view showing a modified form of construction in which the valve is incorporated in a unit that is easily installed and removed.

For purposes of convenience and ready reference, the apparatus will be described as being operative in a vertical position in which the reciprocatory movement of the hammer or weight or its equivalent is up and down; although, it will be readily understood that the apparatus may operate in other positions. Therefore, the descriptive terms employed are by way of example only and not by way of limitation.

The numeral **10** designates in its entirely support means preferably made up of a lower part **12**, in the form of a hammer support or cage, an upper part **14**, which provides or defines an air inlet chamber **16**, and a partition or plate **18** which separates the chamber **16** from the interior of the support or cage **12**. These three parts are rigidly secured together as by a plurality of cap screws **20**. The top part **14** has an upper wall **22** which is extended peripherally in the form of a flange **24** having apertures **26** therein by means of which the structure may be attached beneath an object to which forces are to be transmitted.

The bottom part of the cage **12** is covered by a striker plate **28** which may be attached, as by cap screws **30**, above an object to which forces are to be transmitted, the numeral **32** representing a plate or wall of such object. In FIGURE 1, the cap screws **30** have been

omitted but the apertures for receiving same are shown at 34.

The interior of the cage or support 12 carries energy-conversion means, here a weight or hammer 36, the motion of which is reciprocatory, here up and down; although, as previously indicated, this is not a limitation. The range of reciprocation may be regarded as being established by the stops afforded by the undersurface of the partition 18 and the top surface of the plate 28, but other forms of stop means could be utilized. Also, as will be brought out below, it is not required that the hammer strike either or both of the plates represented by 18 and 28. For purposes of convenience in design, the interior of the cage 12 is cylindrical, which is true also of the configuration or cross section of the hammer. The upper portion of the hammer has a relatively close fit with the cylindrical interior wall of the cage 12 and this fit is supplemented by an appropriate seal, such as an O-ring 38, the top of the hammer thus serving as a piston 40 operative in a power chamber or cylinder 42 existing between the piston 40 and the partition plate 18. The contact between the exterior surface of the hammer and the interior surface of the cage 12 may be quite limited in area and actual guiding of the weight for reciprocation may be a central or axial guide in the form of an upright tubular member 44 rigidly secured to and rising from the plate 28 and coaxially slidably received in a cavity or bore 46 in the hammer.

In the case of FIGURES 1 and 2, the plate 28 has passage means 48 therein which leads to the interior of the tubular member 44 and thence to the cavity 46 via a drilled passage 50 at the lower portion of the tubular member. The bottom of the tube is plugged at 52. A source of fluid under pressure, here an air compressor, is represented schematically at 54 and this is connected via a pressure regulating valve 56 and line 58 to the passage 48. Air supplied to the cavity 46 acts on the hammer at a relatively low compression ratio and serves in this form of the invention as means for biasing the hammer on its return stroke. As shown in FIGURE 4, the air line connection at 58 could be omitted and a spring 60 could be housed within the tubular member to act at one end on the hammer via the inside of the cavity 46 and to act at its other end on the plug 52. The passage means 48–50 will in this case serve as a vent for exhausting trapped air in the cavity 46. The details of the operation of these two forms of the arrangement will be described later. When the air bias of FIGURE 2 is used, a seal, such as an O-ring 62, is used between the tubular member 44 and the bore or cavity 46. The friction involved here is negligible, so that it does not interfere with operation of the apparatus with the spring bias of FIGURE 4. The cross sectional area of the bore 46 is relatively small compared to that of the piston 42. Likewise, the diameter across 46 is but a small proportion of the length of the tubular member 44, whereby the guiding characteristics at 44–46 are materially improved.

Entrapment of air beneath the hammer is avoided by the provision of a vent at 64. If desired, the wall of the cage 12 need not be made continuous. This, as well as other permissible variations will readily occur.

In the assembly of the parts 12, 14 and 18 appropriate seals are used, as at 66 and 68. In the mounting of the structure 10 on the object to be vibrated, as at 32, for example, the cap screws 30 are passed directly through the plate 28 and into the object at 32, but the plate 28 is attached to the remainder of the structure 10 by cushioned fastening means, here comprising a plurality of cap screws, one of which is shown at 70 as including a coiled compression spring 72 which acts between the head of the cap screw and a flange on the bottom of the part 12. The cap screw enters the plate 28 but does not enter the plate 32. Thus, the full force of the reciprocation of the hammer is not transmitted entirely to the structure 10, the means 70–72 serving broadly as cushioning means.

Complementary portions of the parts 12 and 14 are appropriately drilled or otherwise provided with bores or the like to establish outlet or discharge passage means 74 for discharging the power chamber 42 to atmosphere. A flexible line, such as a hose 76 is connected to the passage means by a suitable fitting 78 and is provided at its opposite end with a control valve or cock 80, which may be adjusted to regulate the rate of discharge from the chamber or cavity 42. The hose 76 is shown as broken away at an intermediate portion thereof to indicate that it may be more elongated than illustrated, so that the cock 80 may be located remotely from the apparatus to provide for remote control thereof, which is important, because in many instances apparatus such as that shown at 10 is located in relatively inaccessible areas.

The air compressor or equivalent fluid pressure source is connected by a line 82, which includes a pressure regulating valve 84, to a drilled or cored passage 86 which leads to the inlet chamber or accumulator 16, whereby this chamber may be pressurized to effect the power stroke of the hammer or weight 36. For the purpose of providing communication between the inlet chamber 16 and power chamber 42, the partition plate 18 has centrally thereof (in the present case) a valve opening or part 88 which may be provided as part of an insert 90 which is threaded into the plate 18. With a constant supply of fluid pressure to the inlet chamber 16, opening and closing of the port 88 will cause reciprocation of the hammer 36, in conjunction with exhaust of the chamber 42 via 74–76–80 and action of the biasing means (air bias of FIGURE 2 or spring bias of FIGURE 4) on the weight or hammer 36. The valve arrangement, so far as concerns the valve itself, is essentially the same in FIGURES 1 through 5, and that illustrated in FIGURE 6 presents the same principles but in a different form. In all cases, the embodiments shown are preferred but various other forms could be utilized as their equivalents.

FIGURE 2 shows, by way of example, that the upper wall 22 of the upper part 14 of the structure 10 carries valve structure including a centrally depending integral coaxial sleeve 92 or support which has a bore 94. A generally tubular valve member 96 is vertically slidably carried in the bore 94 and has a lower port-control portion or nose provided with an annular seal in the form of an O-ring 98 which provides the actual valving action in conjunction with the port 88. The valve is in its open position in FIGURE 2, and the O-ring 28 is upwardly or clear of the port 88. FIGURE 3 shows the closed position of the valve, and the O-ring is received within the valve opening. FIGURES 4 and 5 likewise show the valve 96 in its open position. This is true also of the valve (to be described later) in FIGURE 6. In all these cases, with the exception of FIGURE 3, the hammer or weight 36 is at the top of its stroke, which may be regarded as the end of its return stroke. FIGURE 3 illustrates the hammer 36 as being displaced away from the end of its return stroke, which may represent continued travel of the hammer on its power stroke or the hammer in part of its return stroke.

In that form of the invention shown in FIGURES 1, 2 and 3, the top end of the valve bore 94 is closed by a threaded plug 100. This plug intersects and thus closes a diagonal passage 102 leading from the chamber 16 to the bore 94. Hence, since this is closed in FIGURES 1, 2 and 3, it may be ignored, just as if there were no passage at 102. The significance of the passage 102 will occur in connection with the description of FIGURE 5.

Since the valve 96 is essentially tubular, it provides an interior bore in which is coaxially slidably or telescopically carried a plunger or force-transmitting element 104 which projects at its lower end beyond the nose of the valve which contains the O-ring 98 and which engages at its upper end with a resilient force-transmitting or energy-storing element in the form of a coiled compression spring 106 which reacts against a centrally apertured plug 109

threaded into the top end of the valve **96**. In other words, the spring **106** tends to push the plunger **104** downwardly. In this case, a downward limit is established by shoulders **110** respectively on the plunger and valve which engage when the plunger is fully downwardly extended. The plunger is of small diameter than the port **88** so that it is capable of projecting freely through the port. The space between the underside of the plug **100** in the top of the wall **22** of the part **14** and the top of the valve assembly may be regarded as a chamber **114** which, when the valve is open (FIGURE 2) is in communication with both chambers **16** and **42** and which, when the valve is closed (FIGURE 3) is in communication with only the chamber **42** by an axial passage **116** in the plunger, together with the fact that the plug **108** is centrally apertured. A seal, such as an O-ring **118**, surrounds the valve **96** within the bore **94** and thus implements the relationship between these two parts. A rubber or equivalent resilient washer **120** is provided between the bottom of the sleeve **92** and a circular flange **122** integral with the valve **96** for, among other things, absorbing shocks incident to return of the valve to its open position.

The radial flange **122** is part of releasable means for initially holding the valve closed and for applying at least part of the closing force to the valve, the other part of this means comprising quickly releasable elements, here in the form of a plurality of magnets **124** secured to the top of the partition plate **18** as by a corresponding plurality of cap screws **126** threaded into blind tapped bores **128**.

In the operation of that form of the apparatus shown in FIGURES 1, 2 and 3, let it be assumed that FIGURE 2 represents what may be regarded as a starting or initial position of the components. That is to say, the hammer **36** is in its up position, and the valve **96** is open. This condition of the parts may be accepted from the fact that the hammer **36** is biased to the end of its return stroke by the air bias means of FIGURE 2. The same result will follow from the spring bias in FIGURE 4. Hence, fundamentally, the operation may be regarded as the same, except that significant differences will occur in conjunction with the air bias if the pressure regulating valve **56** is utilized to increase the bias at times, which will accelerate the hammer on its return stroke. In conjunction with the air bias, there is actually very little cushioning effect on the power stroke because the air is trapped not only in the cavity at **46** but also within the tubular member **44**, passage **48** and line **58**, since the fluid used here, air, is essentially elastic. Also, the valve **56** may be so constructed as to completely exhaust the biasing air, for purposes to be presently explained.

As air is supplied to the inlet chamber **16**, it also enters the chamber **42** to act against the piston **40**, since the valve **96** is open. Air can also enter the chamber **114** via the passage **116** and the centrally apertured plug **108**. Since the chambers **16** and **42** are relatively close together, being situated just across the port **88** from each other, the air at relatively high pressure acts downwardly on the hammer **36** via the piston **40**, the chamber **42** thus expanding as the hammer **36** moves downwardly, followed by the plunger **104** because of the spring **106**, and as the plunger moves downwardly, the spring **106** is unloaded or releases energy. Thus, the force of the spring that was formerly utilized to act against the plug **108** and thus to hold the valve open now falls to a value less than the valve-closing force developed by the magnetic attraction between the magnets **124** and the flange **122** on the valve. Therefore, the valve closes relatively slowly and cuts off communication between the chambers **16** and **42**. At the same time, communication is cut off between the chambers **16** and **114**, since the lower end of the passage **116** is now below the closure established between the O-ring **98** and the port **88**. Depending upon the pressure, the force imparted to the hammer via the piston causes the hammer to move downwardly on its power stroke. If this force is high enough, the hammer **36** will strike the plate **28** and impart force to the object, as at **32**, to which the apparatus **10** is attached. The chamber **114** is exhausted via **74–76–80** at the same time as the chamber **42** so that only the magnets hold the valve closed; thus, less powerful biasing forces are needed below the hammer for effecting valve opening incident to the return stroke of the hammer. The chamber **114** is charged on the power cycle to aid the magnets in closing the valve.

The rate at which the hammer moves on its return stroke will depend in the first place on the amount of opening provided by the cock **80** in the line **76**, which exhausts the chamber **42**. If the cock is fully closed, there will be no return of the hammer. If the cock **80** is fully opened, the return of the hammer will be relatively rapid. Variations on the rate of return of the hammer may be accomplished by regulating the cock **80** as desired. The discharge passage established in part by the line **76** and cock **80** is relatively restricted as compared to the inlet passage **82–84–86**. It will be clear that the line **76** could be connected at the top of the apparatus, as by replacing the plug **100** with an apertured plug, since in both cases the chambers **42** and **114** would be exhausted to atmosphere. These are among the many modifications that could be achieved within the principles of the present invention. Also, the rate of return of the hammer can be effected by control of the air bias pressure (FIGURE 2); that is, if this pressure is relatively high, the rate of return will be relatively fast. If the cavity **46** is exhausted, as previously suggested, there will be no biasing action on the hammer **36** on the power stroke. Of course, if the apparatus is inverted, then different considerations prevail.

At any rate, and considering now the situation as disclosed basically in FIGURE 2, but with the hammer **36** in its downward position as shown in FIGURE 3, the valve will be closed as also shown in FIGURE 3, and will be held in that position by the magnetic attraction acting on the valve. With the valve closed, the valve chamber **114** is depressurized, leading to the power chamber via passage **116**, the power chamber at this time being depressurized, since the valve is closed as said above. As the work member or piston means **38–40** begins its return movement it starts to build up a valve opening force by acting through the plunger **104** to compress the spring **106**, and as the work member approaches its upper limit the opening force is built up to its predetermined value, which exceeds the holding force of the releasable means or magnetic means **124** so that the latter suddenly releases to incur rapid opening of the valve and a consequent burst of pressure from the inlet chamber to the power chamber, moving the work member or hammer on its power stroke. This of course unloads the means **104–106** and at the same time pressure derived from the inlet chamber (which is now present also in the power chamber) pressurizes the valve chamber **114** via passage means **116**. Since, in the example shown, the valve area within the chamber **114** is equal to the opposite end of the valve exposed in proximity to the port **88**, the valve is balanced and is returned to the influence of the valve-returning force (attraction) of the magnets **124**. This is the simplest situation: in which the amount of valve opening, although large enough to break the valve away from the immediate holding power of the magnets, is still such that the valve is not entirely clear of the "reaching" power of the magnets. Now, where the valve-opening movement is greater, an additional or combining valve-return force can be developed by biasing means compensating for the increased travel of the valve; in the present case such means is represented by the resilient cushioning means **120**, affording enough rebound, so to speak, to assure that the valve does return to within the influence of the attraction of the magnets. Any other spring, etc. could be used. The balancing of the valve is also part of the means combining with the releasable means or magnets to accomplish valve closing.

However, depending upon requirements, these diameters

could be varied so as to add to or detract from the attractive force of the magnets. This will of course have a bearing on the amount of travel of the hammer in its upward direction before the valve opens. For example, if the diameter at **94** is greater than that at **88**, the force resulting from pressure in chamber **16** that acts upwardly on the valve will be greater than the force resulting from pressure that acts downwardly. In other words, the excess force will be subtracted from the spring loading force required to break the attractive force of the magnets, and the valve will open sooner because, as the plunger **104** moves upwardly and begins to load the spring **106**, it will accomplish adequate loading of the spring at a time and value which will be relatively low, since the spring loading force required to break the hold of the magnets will be less than it would were the two diameters in question equal. Conversely, if the diameter at **94** is less than that at **88**, the reverse would be true, since the downward force on the valve from pressure in chamber **16** would be added to the spring loading force required to overcome the magnets and the plunger **104** would have to travel farther before compressing or loading the spring **106** sufficiently to break the grip of the magnets. When the diameter at **94** is greater than at **88** the amount of travel of the hammer will be related to the valve-influencing forces derived from pressure in chamber **16**. The greater the valve-opening force from pressure in **16** the less distance the hammer will travel before tripping the valve. Conversely, when the diameter **94** is smaller than that at **88**, the distance traveled by the hammer will be longer. The greater the valve-holding force the longer the distance the hammer will have to travel before tripping the valve. Also, the pressure in the chamber **16** can be varied via the regulating valve **84**, adding further to the flexibility of the control of the valve, which is more convenient than adjusting the spring **106** via **108**.

The plunger **104** and spring **116** comprise, in the valve-opening means, a lost-motion device capable of releasing energy on the way down and accumulating or storing energy on the way up to build up the valve-opening force to a predetermined value. If the two elements were rigidified, the valve would begin to open as soon as the plunger moved up. One defect in such arrangement is that the immediate opening of the valve in a slight amount causes "cracking," and air from chamber **16** immediately begins to enter chamber **42** and consequently acts downwardly on the hammer **36**. The valve will immediately close and the hammer will again start up, causing further cracking of the valve. This will result in relatively rapid vibration of the hammer, which, although desirable in some circumstances, is sought to be overcome by the present invention, which is one reason why the valve-opening delay means is utilized, residing here in the lost-motion energy-storing device represented by the plunger **104** and spring **106**. If the spring **106** were long enough, it could directly contact the top of the hammer. Likewise, the plunger could be contained in the hammer **36**. These are, of course, mere details of construction.

As the spring **106** becomes increasingly loaded by upward travel of the plunger **104** under influence of movement of the hammer upwardly on its return stroke, the spring becomes increasingly stronger and ultimately accumulates or builds up enough force to overcome the valve-holding force applied by the magnets. Since the magnetic force deteriorates as the flange **122** moves away from the magnets, the valve-holding force may be regarded as deteriorating, which occurs substantially simultaneously with the increased load in the spring **106**, with the result that the spring **106** now has lesser force to overcome and therefore the valve **96** opens immediately and widely, thus avoiding any "cracking" or leaking. As the valve rapidly achieves its open position, the shock incident thereto is cushioned by the bumper **120**. The valve may have a tendency to overtravel the plunger **104**, and the spring **106** will thus be temporarily decreased in load. However, this is immaterial, since the flange **122** is now so far from the magnets **124** as to make the magnetic force, which is now at best a force influencing the valve to return, substantially ineffective at the load value presently in the spring **106**. As the hammer reaches the top of its stroke, the load will be restored to the spring **106** at an adequate value. The above follows from the fundamental principle that the magnetic attraction decreases as the square of the distance between the magnets (here **124**) and the member sought to be attracted (here the valve flange **122**).

Another cycle of operation occurs as a repetition of that already described, since the valve being open permits air again to enter the chamber **42** to act on the hammer piston **40**. As previously described, variations in the length of stroke of the hammer can be regulated by varying the air pressure in the chamber **16** and/or adjusting the valve-loading spring **106** and the rate of reciprocation of the hammer may be accomplished by regulating the cock **80** or the valve **56** between the air source **54** and cavity or bore **46**. Structural changes of the type already indicated will also incur variations in operation.

Apparatus using the control principles just described will produce hammer reciprocation at a relatively low rate as a result of the particular valve-closing forces and the valve-opening control means in opposition thereto. The vibrator having relatively higher frequency but a frequency still below that in the prior apparatus first referred to herein, can be achieved by reliance on air pressure in the chamber **16**, as well as by the addition of a biasing spring applying the valve-closing force, in which case, the magnetic means would not be utilized.

An exemplification of this is shown in FIGURE 5 by way of a conversion of the structure of FIGURE 2. The magnets **124** are removed and are replaced with stops **130**, which have lower threaded ends receivable by the tapped bores **128**. These stops have substantially the same height as the magnets **124** and in this case are engaged by the undersurface of the flange **122** on the valve **96** so that the O-ring **98** cannot pass completely through the valve opening **88**. If a different type of valve is used, the stops could be eliminated or other stops could be provided if necessary. Those shown are by way of example only.

Another addition to FIGURE 5 is a valve-closing spring **132** which acts between the underside of the wall **22** and the top side of the flange **122**, plus the further change consisting in the replacement of the plug **100** by a plug **100***a* which has therein a passage **100***b* so as to communicate the chamber **114** with the chamber **16** via the previously described diagonal passage **102**. In other words, the passage **102**, not used in FIGURE 2, is used in FIGURE 5. A still further change resides in the replacement of the apertured plug **108** with a solid plug **108***a*, thus affording a piston at the top of the valve **96**.

With the hammer **36** in its up position, as shown in FIGURE 5, pressurizing of the chamber **16** results also in pressurizing of the chamber **114** via **102–100***b*, adding a force to that already exerted by the valve-closing spring **132**. As the plunger **104** follows the hammer down on its power stroke as a result of pressure passing from chamber **16** to chamber **42**, the load on the spring **106** is relaxed until it falls to a valve below that exerted by the other valve-closing forces, whereupon the valve closes, the flange **122** stopping against the stops **130** for reasons already described. When the hammer returns by virtue of its biasing means (FIGURES 2 or 4) the upwardly moving plunger **104** begins to load the spring **106** until it overcomes the valve-closing force, whereupon the valve opens. The delayed action evident in the construction of FIGURES 1, 2 and 3 is not available here but the the valve opening is materially more delayed than in the case of a direct connection between the plunger and the valve, resulting in an apparatus having a hammer reciprocating rate of medium value.

In all cases so far described, the plug **100** or **100***a*

can be removed to provide access to the plug **108** or **108***a* for adjustment thereof to vary the loading of the spring **106** between the plug and the plunger. By way of improving the conversion of the structure from FIGURE 2 to FIGURE 5, for example, the plug **100** could be provided with a passage similar to the passage **100***b* and the plug could be rotated to a position in which such passage would register with the diagonal passage **102**. These are merely other characteristics showing the flexibility of the apparatus.

In those cases in which the stroke of the hammer is relatively long, the inner engaging shoulders **110** and **112** between the plunger and the valve will prevent the plunger from falling out of the bottom of the valve. The same result is achieved during disassembly, in any event, and there is no danger that the plunger will become lost.

In the construction shown in FIGURE 6, the basic components are utilized and to the extent that they are the same, similar reference characters are employed. To the extent that there are minor differences, the reference characters are primed. For example, the upper part is shown at **14'** as providing a chamber **16'** having a top wall **22'**, the chamber being supplied with air under pressure via a bore **86'**. The remainder of the structure is the same, except that the valve opening insert **90** is removed and is replaced by a tubular member **134** which forms part of a unit or "capsule" valve assembly **136**. The tubular member **134** is threaded into the partition **18** in lieu of the insert **90** and carries therein a valve **96'** carrying at its lower end an O-ring **98'** which seats in a valve opening **88'** established at a lower portion of the tubular member **134**. The upper end of the valve **96'** carries a threaded plug **108'** between which and one end of a plunger **104'** a spring **106'** acts, the plunger projecting at the bottom of the valve **96'** to function in the manner of the plunger **104** in FIGURE 5. A spring **132'** acts between the underside of the wall **22'** and the top of the plug **108'**, serving the same function as the spring **132** in FIGURE 5. The upper end of a slot **122'** in the plunger **96'** provides one of a pair of stops, the other of which is a set screw **130'** in the tubular member **134**, which limits downward movement of the valve so that the O-ring **98'** cannot pass entirely through the valve opening **88'**. One advantage, among others, of this construction is that the unit assembly **136** may be readily removed for inspection, repair and/or adjustment, simply by removing the top part **14'** of the apparatus.

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. In a vibrator or like apparatus including a fluid-pressure-receivable inlet chamber and a power chamber connected by means including a port to pressurize the power chamber to incur movement of a work member on power and return strokes, the improvement comprising: a valve support juxtaposed relative to the port and including a valve chamber open at one end and closed at its other end; a valve movable in the valve chamber between closed and open positions and having a port-closing portion at one end at the open end of the valve chamber and having its opposite end enclosed by said valve chamber; means providing a passage opening at one end to the closed end of the valve chamber and at its other end to the power chamber for communicating the closed end of the valve chamber with the inlet chamber when the valve is open and with the power chamber when said valve is closed; said valve and valve chamber having a fluid-tight relation to exclude inlet chamber pressure from the valve chamber except through said passage when the valve is open; valve biasing means operative between the valve and work member and operative to be loaded to a valve-opening force at a predetermined value by the work member on its return stroke so as to yieldingly hold the valve in its open position and unloaded to a substantially lower value so as to condition the valve to close upon movement of the work member to a predetermined point in its power stroke; magnetic means exerting a valve-holding force on the valve at a value intermediate said predetermined and lower values to hold the valve closed and operative to release the valve for rapid opening by work-member-loading of the valve biasing means aforesaid predetermined value; means for connecting the inlet chamber to a source of fluid pressure for pressurizing the inlet chamber, the valve chamber via said passage, and the power chamber via said open port for moving the work member on its power stroke and causing closing of the valve; and discharge means for discharging the power chamber and the closed end of the valve chamber when the valve is closed to enable biased return of the work member and consequent reopening of the valve.

2. The invention defined in claim **1**, in which: the port-closing portion of the valve is constructed to enter the port, and annular fluid-pressure seal means is cooperative between said port and portion for sealing the two when the valve is closed while still enabling limited movement of the valve in both directions along its path of movement.

3. The invention defined in claim **2**, in which: said annular seal is an O-ring.

4. The invention defined in claim **1**, including means tending to influence the valve toward its closed position, comprising resilient means between the valve and valve support serving also as a cushioned stop for the valve at its open position.

5. The invention defined in claim **1**, in which: the fluid-tight relationship between the valve and valve chamber is an O-ring seal.

6. The invention defined in claim **1**, in which: the port-closing portion of the valve is constructed to enter the port, and the magnetic means includes a stop interposed between the valve and the partition for stopping the valve in delayed relation to entry of said port by said port-closing portion.

7. The invention defined in claim **1**, in which: the work member is biased on its return stroke by biasing means including a biasing chamber exposed to the work member in opposition to the power chamber and means for supplying and exhausting elastic fluid to and from said biasing chamber.

8. The invention defined in claim **1**, in which: the port is provided in a partition between the inlet and power chambers, the valve and valve support are coaxial with the port and normal to the partition, the valve is movable toward the partition to its closed position, and the magnetic means includes a metallic flange on the valve and external to the support spaced from and parallel to the partition and a plurality of magnets attached to the titions in spaced relation to the flange in the open position of the valve.

9. The invention defined in claim **8**, including: cushion means interposed between said flange and the support to cushion return of the valve to its open position.

10. The invention defined in claim **1**, in which: the area of the valve-closing portions of the valve and the area of the valve-chamber-enclosed end of the valve are substantially the same so as to substantially pressure-balance said valve.

11. The invention defined in claim **1**, in which: the discharge means is controllable as to rate of fluid exhaust.

12. The invention defined in claim **11**, in which: said control means is located relatively remotely from said housing for controlling said discharge means.

13. In a vibrator or the like including housing means having a fluid-pressure-receivable inlet chamber and a power chamber separated by a partition means including

a port, and means including a movable piston means in the power chamber and pressurizible and depressurizible to incur movement of said piston means respectively between first and second limits, the improvement comprising: a valve support exposed to the inlet chamber, including a valve chamber open at one end and closed at its other end; a valve movable in the valve chamber between closed and open positions and having a port-closing portion at one end at the open end of the valve chamber and having its opposite end enclosed by said valve chamber, means providing a passage opening at one end to the closed end of the valve chamber and at its other end to the power chamber for communicating the closed end of the valve chamber with the inlet chamber when the valve is open and with the power chamber when said valve is closed; said valve and valve chamber having a fluid-tight relationship to exclude inlet chamber pressure from the closed end of the valve chamber except through said passage when the valve is open; valve-opening means including biasing means operative between the valve and piston means and loaded to a predetermined value by the piston means at its second limit so as to yieldingly hold the valve in its open position and unloaded by the piston means at its first limit to a substantially lower value so as to condition the valve to close; quick-acting releasable means operative between the housing and valve and exerting a valve-closing force on the valve at a value intermediate said predetermined and lower values to close the valve at said first limit and releasable subsequently to release the valve for rapid opening by the loaded valve-opening means at said second limit; means for connecting the inlet chamber to a source of fluid pressure for pressurizing the inlet chamber, the closed end of the valve chamber via said passage, and the power chamber and piston means via said open port for moving the piston means to its first limit and causing closing of the valve; and discharge means for discharging the power chamber and the closed end of the valve chamber when the valve is closed to enable return of the piston means to its second limit and consequent reopening of the valve.

14. The invention defined in claim **13**, in which: said passage extends end-to-end through the valve and opens at its opposite ends respectively to opposite ends of said valve.

15. In a vibrator or like apparatus having an elastic-fluid-pressurizible inlet chamber connected by means including a port to a power chamber expansible by inlet pressure via the port and contractible when discharged to a lower pressure to move a work member respectively on power and return phases, the improvement residing in means for controlling the transmission of fluid pressure in cyclical bursts from the inlet chamber to the power chamber, comprising: a valve and valve-supporting means carrying the valve for movement between port-opening and port-closing positions; means releasably holding the valve closed and operative to resist valve-opening forces below, and to suddenly release the valve at a predetermined value; valve-opening means operative to create valve-opening forces up to said value for overcoming the effects of said releasable means to suddenly open the port for enabling a burst of fluid pressure from the inlet chamber to enter and rapidly expand the power chamber; means acting on the opened valve and affording a first area exposed to the effects of inlet chamber pressure and tending to keep the opened valve open; and valve-return means operatively combining with the releasable means to effect re-closing of the valve, including means associated with the valve-supporting means and providing a third chamber additional to the inlet and power chambers, a fluid pressurizible and depressurizible area movable therein and effective on the valve in opposed relation to said first area, passage means operative when the valve is open for conducting inlet chamber pressure to said third chamber to pressurize said third chamber area and means operative when the valve is closed for depressurizing said third chamber so as to condition the valve for re-opening.

16. The invention defined in claim **15**, in which: the valve-opening means includes energy-storing means operative between the valve and the work member and loaded by movement of the latter in its return phase to build up said valve-opening force to said value and at least partly unloaded by said sudden release of the valve as said releasable means is overcome.

17. The invention defined in claim **15**, in which: the valve-opening means includes a mechanical element operative between the valve and the work member and actuated by the latter in its return phase to at least contribute to the valve-opening force.

18. The invention defined in claim **15**, in which: the passage means includes a passage portion conducting the third chamber to the power chamber for depressurizing said third chamber area via the contracting power chamber when said valve is closed.

19. The invention defined in claim **15**, in which: the passage means includes a single passage for conducting the third chamber to the power chamber for depressurizing said third chamber area via the contracting power chamber when the valve is closed and for pressurizing said third chamber area from the pressure in the inlet chamber and the expanding power chamber when the valve is open.

20. The invention defined in claim **15**, in which: said areas are substantially equally pressure-affected to provide a substantially balanced opened valve as respects the effects of fluid pressure, and biasing means acts on the valve to supplement said third chamber area in favor of re-closing of the valve.

21. The invention defined in claim **20**, in which: the biasing means is included in the releasable means.

22. The invention defined in claim **20**, in which: the biasing means is included in the valve-return means.

23. The invention defined in claim **15**, in which: the releasable means includes magnetic means in which the attractive force diminishes to a lower value when the valve is suddenly opened as aforesaid, and the valve return means acts on the valve to influence said valve to yield to said force of lower value and ultimately to re-close as the attractive force of the magnetic means takes effect.

24. The invention defined in claim **15**, in which: the valve and valve-supporting means are disposed in facing relation to the port, the supporting means is a housing having an open end toward the port and from which one end of the valve projects as a port-covering and port-uncovering portion including said first area, the opposite end of the housing is constructed to provide said third chamber and the end of the valve within said third chamber affords said third chamber area, and said areas are substantially equally pressure-affected to provide a substantially balanced open valve as respects the effects of fluid pressure thereon.

25. The invention defined in claim **24**, in which: the projecting portion of the valve includes shoulder means and the releasable means includes magnetic means acting on the valve via said shoulder means.

26. The invention defined in claim **15**, including resilient means operative to counteract at least part of the effects of valve movement incident to opening thereof.

27. The invention defined in claim **25**, including resilient means cooperative between the housing and the valve to counteract at least part of the effects of valve movement incident to opening of said valve.

28. The invention defined in claim **15**, including: means for controlling the depressurizing means to regulate the rate at which the third chamber area is depressurized to control the cycle frequency.

29. The invention defined in claim **15**, in which: the areas are constructed to be substantially equally pres-

sure-affected to provide a valve substantially balanced as respects the effects of fluid pressure thereon.

30. The invention defined in claim **15**, in which: the passage means includes a portion leading through the valve from the valve chamber to the power chamber when the valve is closed, the depressurizing means leads from the power chamber to a lower pressure and communicates with the passage portion, and said depressurizing means includes means for regulating same so as to control its depressurizing rate so as to control the cycle frequency.

References Cited by the Examiner

UNITED STATES PATENTS

1,057,594	4/13	Taylor	92—10
1,062,749	5/13	Townsend	91—402
1,264,428	4/18	Norcross	91—7
1,642,074	9/27	Lewis	91—273
2,119,285	5/38	Morgan	91—274
2,120,992	6/38	Seiden	91—224
2,636,406	4/53	Salter	91—206
2,996,071	8/61	Takaoka	251—65

FOREIGN PATENTS

450,656	10/27	Germany.
145,126	6/20	Great Britain.

FRED E. ENGELTHALER, *Primary Examiner.*