Nov. 9, 1965 | A. H. PETERSON | 3,216,328

VIBRATOR OR LIKE APPARATUS OPERATING ON ELASTIC FLUID

Filed Oct. 24, 1963 | 3 Sheets-Sheet 1

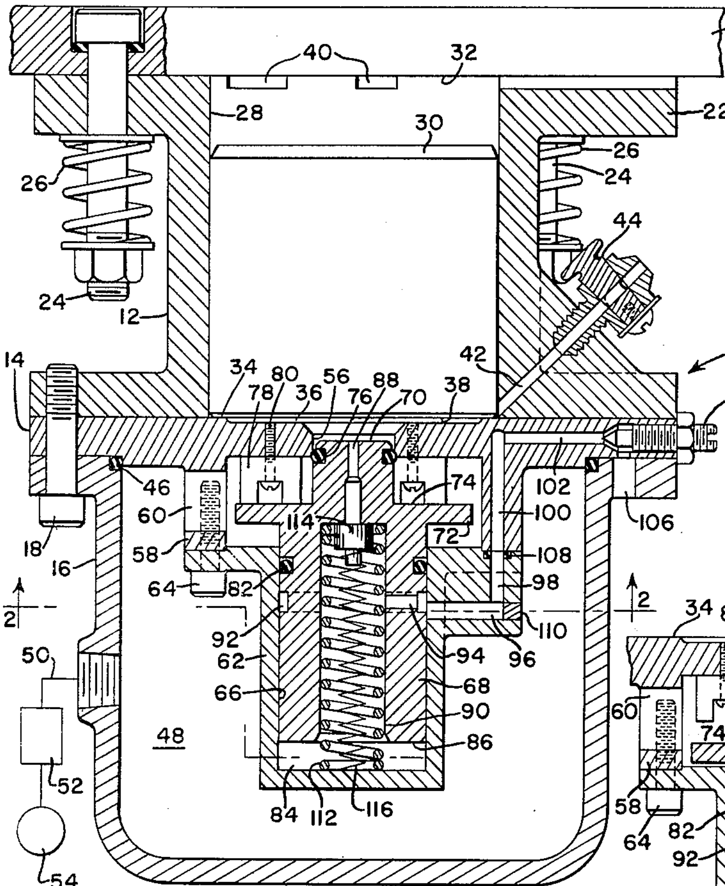


FIG. 1

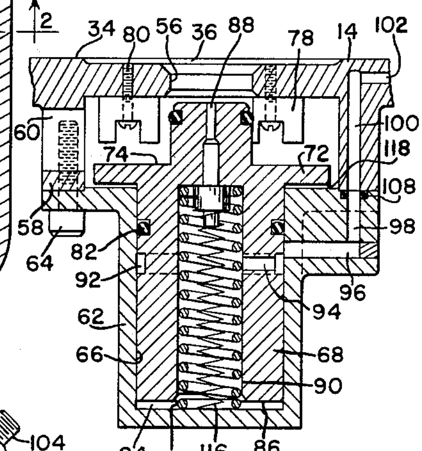


FIG. 3

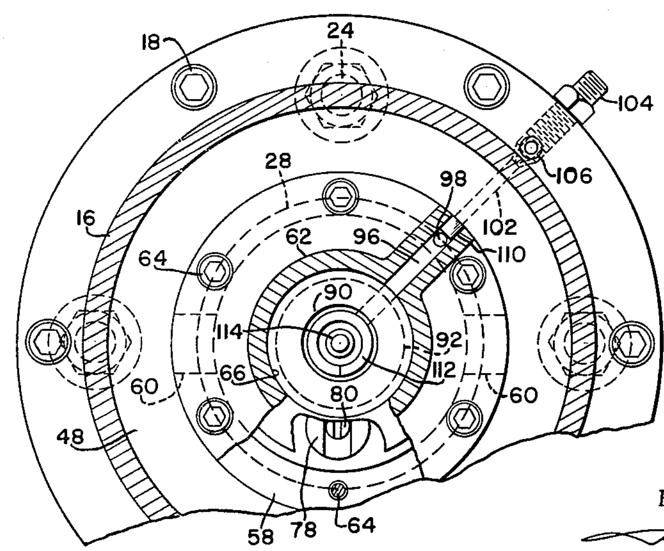


FIG. 2

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VIBRATOR OR LIKE APPARATUS OPERATING ON ELASTIC FLUID

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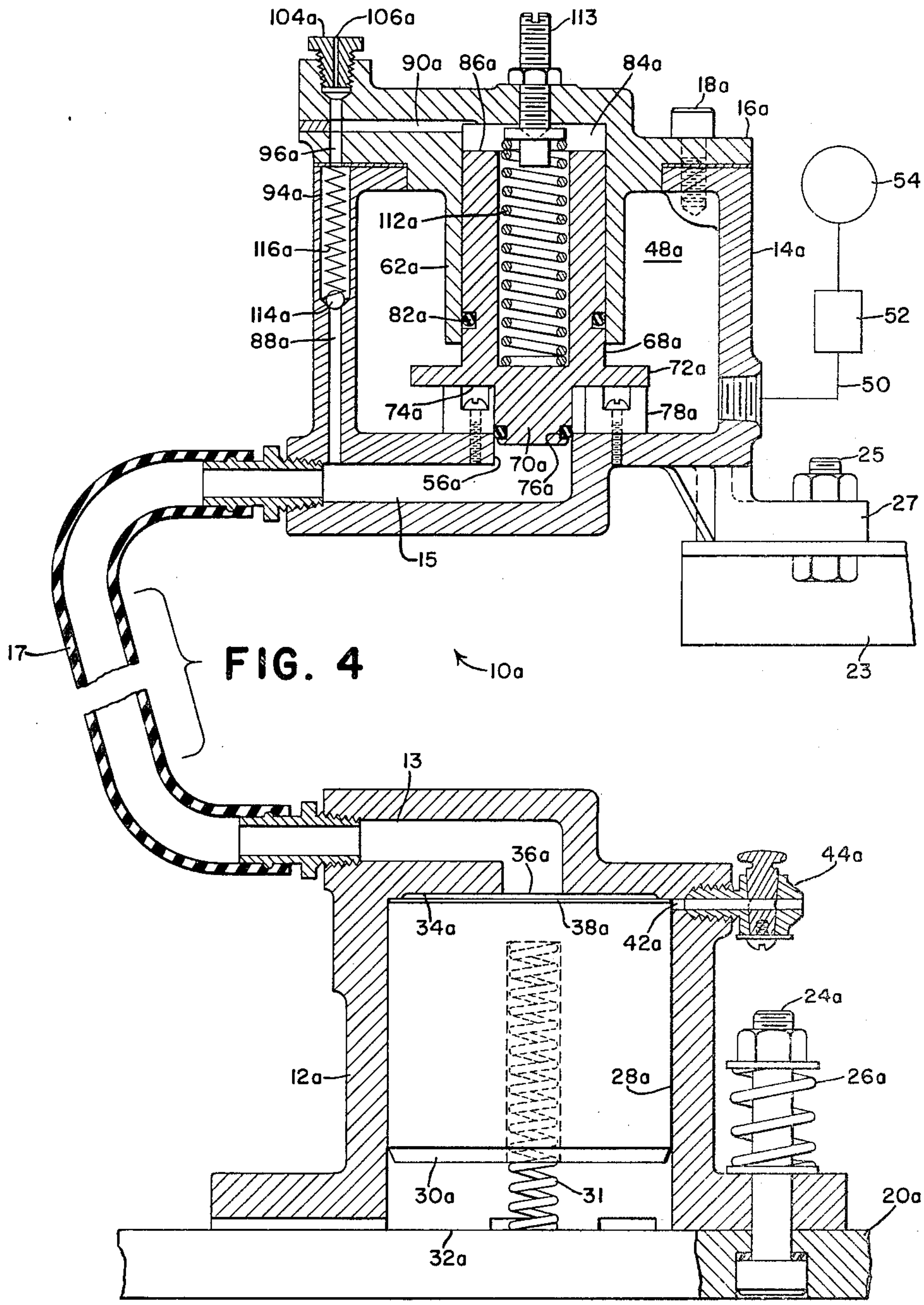


FIG. 4

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VIBRATOR OR LIKE APPARATUS OPERATING ON ELASTIC FLUID

Filed Oct. 24, 1963 3 Sheets-Sheet 3

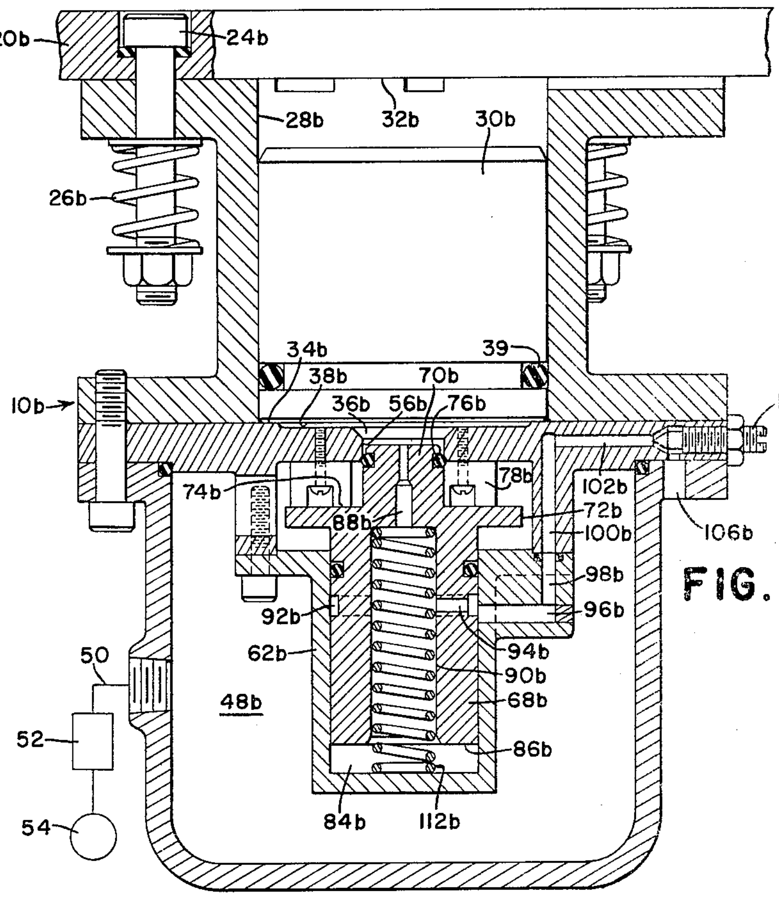


FIG. 5

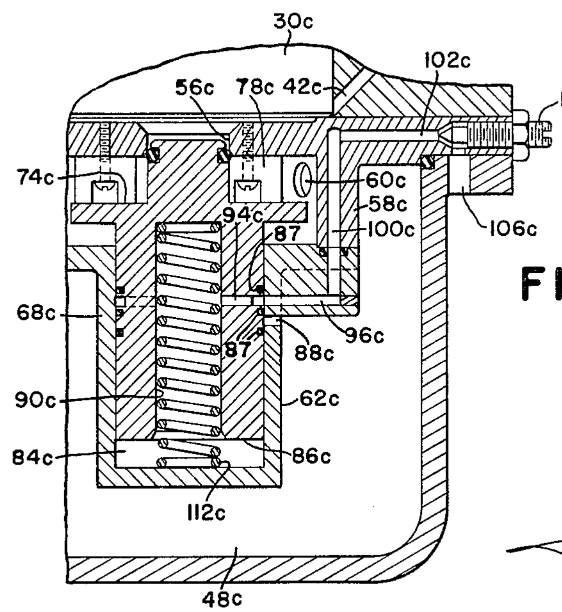


FIG. 6

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3,216,328

# VIBRATOR OR LIKE APPARATUS OPERATING ON ELASTIC FLUID

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22 Claims. (Cl. 91—52)

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 having energy-conversion means 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. 405,953, filed Oct. 23, 1964, as a continuation of now-abandoned Serial No. 177,949, filed March 5, 1962, in which energy-conversion means in the form of 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 accumulator 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 prior art is such that the hammer on its return stroke directly or immediately engages and 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, the return stroke of the hammer must be specially accommodated; e.g., the bias force behind the hammer must be great enough not only to return the hammer but also to open the valve. Where such biasing forces rely on springs, the springs must be large and these in turn introduce cost and space complications. Furthermore, the valve must be relatively close to the hammer to avoid intricate mechanical connections and this virtually precludes remote control of the valve. In other prior art devices of the general type referred to, only relatively high speeds are obtainable, roughly in the order of, say, two thousand to ten thousand vibrations per minute. In the copending application, much lower speeds can be obtained, but according to the present invention, still lower speeds are obtainable by a completely different valve arrangement, and speeds in the range of five hundred blows per minute down to one blow per two or three minutes can be achieved.

It is therefore a principal object of the present invention to provide an improved valve system and control therefor. The improved system features opening of the valve by inlet chamber pressure entirely independent of hammer position, controlling the valve in such fashion that the frequency of its action is varied by the rate of exhaust from a counteracting chamber acting in opposition to the opening force of the inlet pressure or rate at which the inlet chamber is charged. The invention features a valve system in which opening of the valve occurs rapidly and widely, thus avoiding "cracking" or "creeping" of the valve. It is a significant object of the invention to utilize in the control means the application of pressure to pressure-receivable areas so related to the valve movement phases that simple releasable elements may be used to close and retain the valve closed until the pressure rise in the inlet chamber is sufficient to overcome the holding 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 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 of one form of the invention, with a source of fluid pressure and associated lines shown schematically.

FIGURE 2 is a section as seen generally on the line 2—2 of FIGURE 1.

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

FIGURE 4 is a section similar to FIG. 1 but showing a different form of the apparatus.

FIGURE 5 is a section also similar to FIG. 1 but showing a modified construction.

FIGURE 6 is a fragmentary sectional view showing a further modified form of construction.

### *FIGS. 1–3: Description*

In this form of the invention, the vibrator as a whole may be regarded, by way of example, as comprising a casing **10** made up basically of three coaxial parts **12**, **14** and **16** rigidly but removably joined together by a circle of cap screws **18**, parts **12** and **16** being appropriately flanged to sandwich between them the marginal portion of part **14**. In the illustrated use-environment, the unit is suspended from a typical object to be vibrated (represented at **20**) and hence part **12** is uppermost; 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 an attaching flange **22**, apertured to receive a circle of bolts **24** including cushion springs **26**.

Part **12**, which may be a casting, forms a cage or support **28** within which energy-conversion means such as a hammer or its equivalent mass **30** is reciprocable on alternate strokes (here vertical) between upper and lower limits such as, respectively, the under surface **32** of object **20** and the opposed surface **34** of central part **14**, which here serves as a partition between parts **12** and **16**. That portion of cage **28** between hammer **30** and partition **14** establishes a power cylinder or expansive chamber **36**, shown contracted in FIG. 1 because the hammer is down but capable of expansion as the hammer moves up. The bottom 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 cage **28** is vented at **40** to avoid trapping air behind the hammer as the hammer, slidably fitting the interior wall or cylinder of the cage, reciprocates without the benefit of seals and depends for lubrication on lubricant entrained in the elastic fluid, hereinafter sometimes called simply compressed air. As will be explained subsequently, a sealed piston and hammer may be utilized. For the present, the presence or absence of a seal may be temporarily ignored.

As the hammer moves by gravity bias from an upward position toward that shown in FIG. 1, air must be discharged from the chamber **36**, preferably by some means other than relying on leakage between the piston and cage **28**. In the first place, this leakage is normally too small, it is irregular and it cannot be positively controlled. Therefore, a controlled discharge is provided, here by passage means **42** through the wall of the cage and equipped with a variable orifice, effectuated here by a cock **44**. Hence, the piston-cage leak can be disregarded, as further evidenced by the absence of a special seal between parts **12** and **14**, whereas a seal **46** (here a typical O ring) is used between parts **14** and **16**, because the inlet chamber **48** within the part **16** cannot reconcile leakage and efficient operation.

Inlet chamber **48** is constantly pressurized by an inlet line **50** which may be connected by a valve **52** 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. Valve **52** may be any well known flow control valve which functions to "bleed" the air into inlet chamber **48**, or it may be 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 part or plate **14** 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 plate **14** within inlet chamber **48** has an integral circular depending cup **58** provided with circumferentially spaced openings **60** communicating chamber **48** with the interior of the cup. The rim of this cup coaxially mounts a valve support or housing **62** via cap screws **64**, and this housing has therein a valve bore **66** coaxial with port **56**. A valve **68** is axially slidably carried in this bore and projects at one end (here its top end) through the open or port-proximate end of housing **62**, being provided thereat with a reduced cylindrical port-control portion **70** and 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 plate **14** by screws **80**, attracts the valve to its closed position via metallic flange **72**. This attractive force is somewhat less than the force on area **74** at predetermined pressure 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, chamber pressure force on area **74** will have to exceed the magnetic force, plus other forces to be noted later, in order to open the valve (FIG. 2). This can be termed the value of the predetermined force. 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 **68** and valve bore **66** and frictional drag of another seal **82**, here also an O ring, between the valve and the bore, besides strength of magnets, amount of valve opening etc.

Seal **82** operates as means isolating the lower interior of the valve bore, designated as a valve chamber **84**, from inlet chamber **48** when valve **68** 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 upwardly or away from partition plate **14**, which phase of operation is not affected by discharge passage **42–44** or by leakage past piston **38**.

Now, with the hammer "up" and valve **68** 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 passage **42–44**. To accomplish this requires that some means be provided to return the valve automatically to closed position; that is, without, for example, closing line valve **52**.

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 lead inlet chamber pressure to valve chamber **84** where it will act on a second pressure-receiving area **86** at the end of the valve opposite to the first area **74**. It will be appreciated that when valve **68** is open, the whole upper end thereof is then acted on by inlet chamber pressure; and in effect the whole lower end **86** is exposed to valve chamber **84**.

Valve **68** has here an axial through passage **88** opening at valve end **70** and made up of a series of counterbores including a relatively large bore **90** which opens at valve end **86** and thus to valve chamber **84**, but this passage is effective only when valve **68** is open, for when the valve is closed (FIG. 1), passage **88** is cut off from the inlet chamber.

Valve chamber **84**, in addition to being connectible via passage **88** to inlet chamber **48** (when valve **68** is open, FIG. 3), is vented to a lower pressure than inlet chamber pressure, e.g., atmosphere, by an outer annular groove **92** in valve **68**, a radial bore **94** in the valve which leads from groove **92** to valve bore **90** and thus to passage **88**, and a radial passage **96** in valve housing **62** which is always in register with groove **92** (compare FIGS. 1 and 3) and which leads to atmosphere via a series of connected passage portions **98**, **100** and **102**, a needle valve **104** and alined bores providing an outlet **106**. Needle valve **104** is a means for regulating the vent passage and cock **40** is another means for regulating power chamber discharge passage **42**. The specific passage arrangement is deemed to be novel as to the use of the central valve passage **88–90** for the dual use described; although, the equivalent of that system is regarded as broadly novel irrespective of details.

In keeping with adequate sealing of the inlet chamber while valve **68** is closed, a seal at **108** is provided at the junction of passages **98** and **100**. A plug **110** is shown as closing the outer end of passage **96** after drilling.

Valve bore **90** is shown as containing a coaxial coiled spring **112** acting between the valve and the closed end of valve housnig **62**. Although not absolutely necessary, such spring has practical advantages in supplementing the magnetic means, such as overcoming the "break away" resistance of the O ring **82**, enabling the use of magnets of smaller force, and serving as a cushion against extreme valve-opening movement.

A check valve **114** normally closes passage **88** at the shoulder formed by the junction of that passage with valve bore **90**, being 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 **62**.

*Operation: FIGS. 1–3*

The starting positions of the parts can be those shown in FIG. 1. Line presusre via **54–52–50** builds up in inlet chamber **48** to the pre-set amount; e.g., 30 p.s.i.g., while valve chamber **84** is vented to atmosphere via **90** etc. as regulated by needle valve **104**. Passage **42**, controlled by cock **40**, has a lesser restriction to fluid flow than outlet **106** as affected by needle valve **104**. Inlet chamber **48** is sealed against leakage by seals **46**, **76**, **82** and **108**, valve seal **82** isolating valve chamber **84** from the inlet chamber and port seal **76** isolating power chamber **36** from the inlet chamber. Pressure rise in inlet chamber **48** acts thus against pressure area **74** on valve **68** until it overcomes the attractive or holding force of magnets **78** plus springs **112** and **114** which force is, say, twenty-one pounds as against a pressure area at **74** of, say, 700 square inches, in which case the valve will quickly open at 31 p.s.i. in the inlet chamber, give or take a pound or two because of frictional drag and other small variables. The rapidity of valve opening occurs because as flange **72** breaks away from magnets **74**, the magnetic attraction deteriorates. This predetermined pressure becomes the minimum pressure at which the valve will open when the valve chamber is at atmosphere.

The valving intervals are here determined by the speed at which the effect of inlet pressure on area **74** builds up to the preset value via the flow control valve. The needle valve **104** is adjusted to assure discharge of the valve chamber **84** prior to next build-up and yet allows a pressure rise in the valve chamber on the power cycle to close the valve.

When valve **68** opens, inlet chamber pressure rushes into power chamber **36**, acting much as an explosive burst on piston **38** to drive hammer **30** upwardly. Whether or not the hammer strikes surface **32** of object **20**, a relatively powerful impulse will result, jarring the object or applying other desired force to an equivalent object. Although the discharge passage **42–44** is so restricted relative to the charge of air bursting into power chamber **36** as to have no material effect thereon, adjustment of this passage by cock **44** will determine the rate of return of the hammer. The hammer should reach or substantially reach its return limit (surface **34**) before valve **68** re-open after closing following its opening action just described.

Valve **68** closes because of force developed in valve chamber **84** to counteract the valve opening force, which will be clear by recognizing that when valve **68** 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 **86**, 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 **68** opens port **56**, there will be a pressure drop in the inlet chamber. 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 three distinct advantages: First, it overcomes frictional drag between valve **68** and housing **62** as well as overcoming breakaway resistance of seal **82**. Second, it serves as a cushion or bumper for the valve during valve opening and avoids direct contact between valve flange **72** and the proximate marginal portion of valve housing **62** (note space **118** in FIG. 3). Third, spring **112** permits use of weaker magnets and gives the valve an initial push within the attractive "reach" of the magnets so that the magnets complete the valve-closing action. (Another form of the invention will be covered below wherein a valve spring such as spring **112** can be adjusted.)

One feature of the O ring **76** on valve portion **70** will become apparent: Since the O-ring can partially enter port **56** while closing same, the height of the magnets need not be so carefully controlled so long as the magnets stop valve flange **72** after (not before) the O ring enters the port. That is to say, the valve may have limited overtravel but no undertravel on closing, but overtravel is more easily accommodated by the control disclosed here. Overtravel, however, should not be excessive, since it merely adds frictional drag. It is preferred that port **56** have a slight countersink around its bottom edge as shown. This avoids one disadvantage of a poppet valve with conical seating surfaces, which allow for no such overtravel.

Now, with valve **68** closed, there again occurs the isolation of chambers **48**, **36** and **84** from one another. Air let into chamber **84** when the valve opens ultimately vents off via the passage **94** etc. to outlet **106**. Air from power chamber **36** finds an easier exit via passage **42** and cock **44** and will therefore not open check valve **114**. The rates of discharge of the two chambers **36** and **84** may be independently controlled by cock **44** and needle valve **104** respectively. (A form of the invention without the check valve **114** and using the valve chamber vent passage for discharging the power chamber will be described subsequently herein.)

In FIGS. 1–3, the power chamber discharge passage **42–44** may be controlled, whereas discharge via leakage past the piston **38** cannot. Further, as already stated, passages **42–44** and **94–104** can be regulated independently of each other, since check valve **114** separates the two.

It will be clear that valve **68** closes rapidly because of the magnets, once the pressures are "balanced." The time interval preceding re-opening will depend upon pressure build-up in the inlet chamber versus rate of discharge of valve chamber **84**, and this in turn depends upon the setting of needle valve **104**, which will follow from the observation that, if the needle valve is fully closed immediately following closing of valve **68**, air trapped in valve chamber **84** would prevent valve **68** from opening.

It will be seen that higher pressures can be introduced into the inlet chamber **48**, via the pressure regulator **52**, than the preset minimum or amount 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. It should be recalled that when the flow valve is used the needle valve is not critical and the intervals are controlled by the rate at which the inlet chamber rises to the preset tripping pressure. When the pressure regulator is used the air is dumped into the inlet chamber and the control is had by the rate at which the valve chamber is discharged. When the regulator is used any pressure above the preset minimum can be used, for the valve chamber is then discharged to a pressure approximately 30 p.s.i. lower than the inlet pressure. 30 p.s.i. is used as an example, for the preset pressure can be any one desired by choosing the relationship of the magnet strength to the area **74**.

By way of preliminary summary, it has been shown that regulation of a device capable of developing forces up to thirty-five foot pounds can be achieved to produce a range of impulses from 500 per minute down to one per two or three minutes. Regulation is accomplished by variation and adjustments of needle valve **104**, cock **44**, passage **88**, strength of magnets **78** in relation to area **74**, etc. A system employing check valve **114** is desirable where valve **52** is a pressure regulator and where no seal is provided between piston **38** and power chamber **36**. Omission of the check valve when used with a pressure regulator at **52** would preclude desirable low-speed operation in most conditions.

The foregoing are features of FIGS. 1–3. Other features, usable alone or with those of FIGS. 1–3, will be developed below.

*FIG. 4; Description*

The basic features of construction of FIGS. 1–3 are repeated here, with certain differences to be pointed out as the description proceeds. Where fundamental similiary exists, accompanied by structural differences, reference numerals employed in FIGS. 1–3 will be used with the suffix *a*, and uneven numerals will designate further structure.

The FIG. 4 design has the apparatus **10*a*** made up of parts **12*a***, **14*a***, and **16*a***, the latter two forming inlet chamber **48*a*** and part **12*a*** providing cage **28*a*** in which hammer **30*a*** is reciprocatable. Here, however, the parts are reversed as to FIG. 1, i.e., inlet chamber **48*a*** is above and power chamber **36*a*** is below, which requires that hammer **30*a*** be biased upwardly, as by a spring **31**, away from lower limit **32*a*** on object **20*a*** and back toward upper limit **34*a***. A further difference here is that inlet and power chambers **48*a*** and **36*a*** are or can be relatively remote from each other, depending upon the length of fluid line or conduit **17** that extends between passages **13** and **15** respectively in parts **12** and **14**. In this respect, however, passages **13** and **15** and conduit **17** are regarded as but an extension of the power chamber, since passage **13** is part of **36*a*** and **15** leads to port **56*a***, which is controlled by valve **68*a*** in valve housing **62*a*** carried by parts **14*a*** and **16*a***. In other words, the lower portion of part **14*a***, in which port **56*a*** occurs, along with passage **15**, conduit **17** and passage **13** affords the fluid pressure transmission means which is the broad equivalent of FIG. 1. One advantage of FIG. 4 is that the power and inlet chambers may be located remotely from each other. That portion of the apparatus comprising the parts **14*a*** and **16*a*** as united by cap screws **18*a*** is shown as being affixed to a support by bolts **25** and an attaching leg **27**.

Valve **68*a*** is substantially identical to valve **68** as to port control portion **70*a***, seals **76*a*** and **82*a***, flange **72*a***, pressure areas **74*a*** and **86*a***; valve support **62*a*** has a valve chamber **84*a*** enclosing valve area **86*a*** and carries a spring **112*a***, but in this case the force of the spring can be varied by an adjusting screw **113**; and magnets **78*a*** operate on valve flange **72*a*** as before.



Another difference from FIG. 1 occurs in the location of passage **88*a*** in a wall of part **14*a*** rather than in valve **68*a***. This passage has a check valve **114*a*** loaded by spring **116*a*** in counterbore **94*a*** which leads via passage **96*a*** to a restricted outlet **106*a*** provided in a drilled plug **104*a*** rather than via a needle valve as at **104** in FIG. 1. Passage **90*a*** from valve chamber **84*a*** intersects passage **96*a*** and thus also leads to outlet **106*a***. Variation of valve chamber discharge can be obtained however by changing to differently orificed plugs like **104*a***. This adjustment is of course in addition to and independent of the power chamber discharge via passage **42*a*** and cock **44*a***.

Passage **88*a*** leads to power chamber "extension" **15** and thus is closed to inlet chamber **48*a*** when valve **68*a*** is closed but is open to the inlet chamber pressure when the valve is open, as in FIG. 1. Check valve **114*a*** has the same function as check valve **114** of FIG. 1. Line pressure is supplied by means of components **50**, **52** and **54**, which are the same as in FIG. 1.

*Operation: FIG. 4*

In general, operation follows that of FIG. 1. Inlet chamber **48*a*** is charged from line **50** until pressure rise acting on valve area opens valve **68*a*** and the burst or rush of air to power chamber **15–17–13–36*a*** forces piston-hammer unit down. Inlet chamber pressure rise in passage **15** lifts check valve **114*a*** and is applied to upper valve area **86*a*** via passage means **94*a***, **96*a*** and **90*a*** and valve chamber **84*a***, counteracting the valve opening force until the valve is closed by magnetic means **78*a***. In this case, piston-hammer unit moves on its return stroke because of return spring **31** but the action is the same, power chamber **36*a*** etc. being discharged at **42*a*–44*a*** rather than opening check valve **114*a*** (now closed as inlet and valve chamber pressures "equalize"). Adjustment of screw **113** enables variation of spring load on valve **168*a*** to change the amount of inlet chamber pressure required to open valve **68*a***; e.g., increasing load on spring **112*a*** increases inlet chamber pressure necessary to overcome magnets plus spring. Spring **112*a*** serves also the cushion or bumper function of spring **112**. Other functional characteristics of FIG. 1 will be readily recognized and need not be elaborated.

*FIG. 5: Description*

This form of the invention is identical to FIG. 1 except that check valve **114** and its spring **116** are omitted, as are power chamber discharge passage **42** and cock **44**, and the hammer piston is provided with a seal. In the interests of clarity, certain of the reference numerals used in FIG. 1 will be repeated, sufficed by the letter *b*. Thus, the apparatus **106** has a hammer cage **28*b*** and inlet chamber **48*b***, the latter being charged by line pressure at **54–52–50** to open valve **63*b*** and charge power chamber **36*b***, piston **38*b*** acting to move hammer **30*b*** away from limit **34*b*** toward limit **32*b*** on object **20*b*** to which the apparatus is attached by bolts **24*b*** and cushion springs **26*b***.

Valve **68*b*** is carried by valve housing **62*b*** and is controlled by magnets **78*b*** and flange **72*b*** and valve chamber **84*b*** in conjunction with valve areas **74*b*** and **86*b***. Valve passage **88*b*** opens for valve port-control portion **70*b*** directly to valve spring bore **90** without a check valve, and spring **112*b*** operates as spring **112** does in FIG. 1. Passages **92*b***, **94*b***, **96*b***, **98*b***, **100*b*** and **102*b*** lead valve chamber **84*b*** and passage **88*b*** to outlet **106*b***, which is controlled by needle valve **104*b***.

Since piston **38*b*** is sealed, as by O ring **39**, no air leakage will occur between the piston and cage or cylinder **28**. Without a check valve, such as **114**, in passage **88*b***, power chamber discharge will occur via **88*b*–106*b*** and a separate power chamber discharge, as at **42–44** of FIG. 1, is not required. With the exception of these differences, other structural characteristics of FIG. 1 occur in FIG. 5 and need not be described in detail.

*Operation: FIG. 5*

Operation here is identical to that of FIG. 1 with the exception of differences brought about by the sealed piston and the omission of the check valve from passage **88*b*** and the further omission of power chamber discharge passage means **42–44**. Valve opening is the same as in FIG. 1 (or FIG. 4). When valve **68*b*** opens, inlet pressure charging power chamber **36*a*** via port **56*b*** also charges valve chamber **84*b*** via passage means **88*b*–90*b***, following by closing of the valve as before. Valve chamber **84*b*** is then discharged via outlet **106*b***, also as before. But in this case, the same passage, i.e., **88*b*–90*b*–94*b*–106*b***, serves also as the power chamber discharge passage. The same would be true in FIG. 4, if the piston were sealed and check valve **114*b*** and passage means **42*a*–44*a*** omitted. It will be seen that the present vent passage **94*b*–106*b*** could be eliminated and replaced by a power chamber discharge as at **42–44** of FIG. 1 or **42*a*–44*a*** of FIG. 4.

Characteristics of FIG. 5 are these: the seal **39** is apt to prevent air-entrained lubricant from reaching the piston-hammer walls beyond the seal; and power and valve chambers **36*b*** and **84*b***, respectively, discharge at the same rate. On the other hand, considerable economy is available in that two separate passages and controls need not be provided. For real economy but without control, both outlets **42** (**42*a***)–**44** (**44*a***) and **106** (**106*a***) could be eliminated along with piston seal **39**, reliance being placed on piston-cage leakage for exhaust of both power and valve chambers via **88** (FIG. 1) or **88*b*** (FIG. 4). The characteristics of this have already been covered under FIGS. 1–3.

*FIG. 6: Description*

This figure is a substantial repeat of a portion of FIG. 1, with some of the attributes of FIG. 4, and the suffix *c* is used on representative numerals. The basic difference from FIGS. 1, 4 and 5 resides in means for admitting air from the inlet chamber to the valve chamber. In FIG. 1, for example, this is accomplished axially of valve **68** when the valve opens and air enters valve passage **88** as it rushes through port **50**. In FIG. 5, admission occurs radially of the valve and directly from the inlet chamber.

Representative parts appearing in FIGS. 1 and 4 are piston **30*c***, inlet chamber **48*c***, valve housing **62*c***, housing support cup **58*c*** having openings **60*c***, valve **68*c*** with pressure areas **74*c*** and **86*c***, the latter operating in valve chamber **84*c***. The valve is, as before, closed by magnetic means as at **78*c***, to block port **56*c***. Valve **68*c*** is without an axial passage as **88** in FIG. 1 but does have bore **90*c*** in which spring **112*c*** is contained and to which a cross passage **94*c*** in the valve leads from the exterior of the valve.

Valve housing **62*c*** has a pair of axially spaced apart radial passages **88*c*** and **96*c*** and valve **68*c*** carries three annular seals at **87** for purposes to presently appear. Passage **96*c*** leads ultimately to outlet **106*c*** via passage portions **100*c*** and **102*c*** and needle valve **104*c***. The power chamber is discharged by a passage **42*c*** which has a control cock, not shown.

*Operation: FIG. 6*

When valve **68*c*** is closed, its cross passage **96*c*** is in register with valve housing passage **96*c*** and thus valve chamber **86*c*** is vented, here to atmosphere, via outlet **106*c***, since passage **96*c*** leads there by way of passage portions **100*c*** and **102*c***. Passage **88*c***, although open to inlet chamber **48*c***, is nevertheless blocked by the wall of valve **68*c***; i.e., passage **88*c*** is out of register with valve passage **94*c***.



The effect of inlet pressure then rises to a value sufficient to open the valve, acting on the valve area **74*c*** as before, and air rushes into the power chamber, also as before. Since valve **68*c*** has no central passage like **88** in FIG. 1, and there is no passage like **88*a*** in FIG. 4, there is now no communication between the power chamber and the valve chamber **84*c***. But, the valve chamber is nevertheless charged from the inlet chamber because, as the valve opens, its cross passage **94*c*** moves out of register with housing discharge passage portion **94*c*** and into register with charging passage **88*c***, which is in direct communication with inlet chamber **48*c***. Broadly, as in the other modifications disclosed here, the valve chamber is charged or pressurized by inlet chamber pressure as an incident to valve opening. In the one case, the passage means is effectuated upon opening of port **56** (**56*a***, **56*b***) and in the other case by registering passages **94*c*** and **88*c***; although, the port **56*c*** is also opened for its power-chamber-charging function.

*Summary*

Features of the invention common to all forms thereof will readily suggest other variations. Subsidiary aspects peculiar to fewer than all forms can be easily adapted to others; e.g., the passage means **88*a*** of FIG. 4 could be used in FIG. 1; likewise the passage means **88*c*** of FIG. 6; the remote disposition power and inlet chambers of FIG. 4 could be used in FIG. 1. Omissions and additions among the modifications can be availed of where performance, capacity, cost etc. factors make that desirable. These and other alterations progressing from what is disclosed will readily occur to those versed in the art, all without departure from the spirit and scope of the invention.

What is claimed is:

**1.** In a vibrator or like apparatus having an elastic-fluid-pressurizable inlet chamber connected by means including a port to a power chamber expansible by inlet pressure via the port and contractable when discharged to a lower pressure to incur movement of 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 means carrying the valve for movement between port-opening and port-closing positions; means releasably holding the valve initially closed and operative to resist valve-opening forces below, and to suddenly release the valve at a predetermined value; means operative by the valve and affording a port-control portion covering the port in the closed position of the valve and presenting a first area exposed to the power chamber exclusively of the inlet chamber and uncovering the port in the open position of the valve and exposed to the effects of inlet chamber pressure in a valve-opening direction; means acting on the valve and presenting a second area exposed to the effects of inlet chamber pressure in a valve opening direction and receivable of the effects of inlet chamber pressure to create a valve-opening force at said value for overcoming said releasable means so as to suddenly open the port and thereby pressurizing both areas so as to tend to keep the valve open; and valve-return means combining with the releasable means to effect re-closing of the valve, including means associated with the valve and providing a third chamber additional to the inlet and power chambers, a fluid-pressurizable and -depressurizible third area movable in said third chamber and effective on the valve in opposed relation to said first and second areas, passage means operative when the valve is closed to conduct said third chamber to a pressure lower than inlet chamber pressure so as to enable opening of the valve via said second area and means operative when the valve is open to pressurize said third area, said areas being so constructed relative to each other that the pressure effects on the third area counteract at least in part the pressure effects on the first and second areas that tend to keep the valve open whereby to condition the valve for re-closing.

2. In a vibrator or like apparatus including an elastic-fluid-pressurizable 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 in accompaniment with movement of a work member respectively in power and return phases, the improvement residing in means for effecting the transmission of inlet chamber pressure to the power chamber in cyclical bursts via the port in alternation with discharge of the power chamber to incur expansion and contraction thereof; comprising valve structure disposed in proximity to the port and including a support and a valve carried by the support for movement between port-opening and port-closing positions, valve opening and closing means including first and second pressure-responsive areas acting in opposite directions on the valve and effective upon changes in pressure differential therebetween to determine the direction of valve movement, a valve chamber separated from the power chamber at least in part by the valve and containing the second area, and means releasably holding the valve closed and operative to resist valve-opening forces below, and to suddenly release the valve at, a predetermined value, said first area being exposed to inlet chamber pressure and effective when the pressure differential exists in its favor to incur a valve-opening force up to said value for overcoming the releasable means and thus to suddenly open the port and said second area combining with the effects of the releasable means to effect reclosing of the valve when the pressure differential in favor of the first area is at least partly removed; and valve cycling means operative when the valve is closed to depressurize the valve chamber to a pressure lower than that of the inlet chamber to cause a pressure differential to exist in favor of valve opening and operative when the valve opens to connect the valve chamber to the inlet pressure and thus to change the pressure differential in favor of valve closing.

3. The invention defined in claim 2, in which: said valve-opening force is developed by pressurizing of said first area mechanically independently of the work member.

4. The invention defined in claim 2, in which: said valve cycling means has a passage system which includes a first passage portion leading from the valve chamber to the inlet chamber for pressurizing said second area when the valve is open and a separate second passage portion leading from said valve chamber to said lower pressure and exclusively of the power chamber when the valve is closed.

5. The invention defined in claim 4, in which: the valve includes control portions controlling said passage portions according to the position of the valve.

6. The invention defined in claim 4, in which said first passage portion includes a check valve opening said first passage portion to the effects of inlet chamber pressure and closing against the discharge of the valve chamber to the power chamber whereby said area is compelled to lead to said lower pressure by said second passage portion.

7. The invention defined in claim 2, including biasing means acting on the valve in a closing direction.

8. The invention defined in claim 2, in which: the releasable means comprises magnetic means.

9. The invention defined in claim 2, in which: the valve and valve support are arranged in coaxial relation to the port and the valve includes a port-control portion constructed to enter and close the port to withdraw from and open said port.

10. The invention defined in claim 9, in which: the port-control portion includes an annular seal cooperative with the interior of the port in the port-closing position of the valve.

11. The invention defined in claim 9, in which: the releasable means includes a plurality of magnets arranged concentrically about the port.

12. The invention defined in claim 2, in which said valve cycling means has a passage system which includes a first passage portion between the inlet and valve chambers for pressurizing said second area when the valve is open, a second passage portion leading to said lower pressure exclusively of the power chamber, and further passage means is provided for discharging the power chamber.

13. The invention defined in claim 12, including separate means for respectively controlling the rates of fluid flow through said second passage portion and said further passage means.

14. The invention defined in claim 2, in which: the valve support is a cylinder having an open end facing toward and axially alined with the port and having an opposite closed end, the valve is a piston slidably carried by and in fluid-tight relation to the cylinder and has at the open end of the cylinder a piston portion providing both a port-control portion and said first area and has at the closed end of the cylinder an end portion affording said second area, and said last-named end of the valve and the closed end of the cylinder provides said valve chamber.

15. The invention defined in claim 2, including: spring means acting in a closing direction on the valve, and means for varying the force of said spring means.

16. The invention defined in claim 2, in which: the valve support is a cylinder having an open end facing the port in coaxiality therewith and an opposite closed end, the valve is a piston having opposite ends respectively at said open and closed cylinder ends, the valve end at said closed end cooperating therewith to afford said valve chamber and said second area and the valve at its end at the open cylinder end affording a port-control portion and said first area, and the diameter of the valve at its end within said valve chamber being equal to the diameter thereof at its opposite port-proximate end, said port-control portion being of reduced diameter.

17. The invention defined in claim 2, in which: said valve cycling means has a passage system which includes a first passage portion extending through the valve from the first area portion to said second area and a second passage portion leading said valve chamber to said lower pressure, said first passage portion having a check valve openable toward said valve chamber and closable toward said first area portion, a first spring means is contained within the first passage portion to act on the valve in a closing direction and a second spring is also disposed within said first passage portion and biasing the check valve closed.

18. The invention defined in claim 2, including means for adjusting the rate of discharge of the valve chamber so as to regulate the valve-cycling frequency.

19. The invention defined in claim 2, in which the valve cycling means has a passage system which is operative when the valve is closed to depressurize the valve chamber via the contracting power chamber.

20. The invention defined in claim 2, in which the valve cycling means has a passage portion by means of which the power chamber is contractible when the valve is closed.

21. In a vibrator or like apparatus including 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 in accompaniment with movement of a work member respectively in power and return phases, the improvement residing in means for effecting the transmission of inlet chamber pressure to the power chamber in cyclical bursts via the port in alternation with discharge of the power chamber to incur expansion and contraction thereof; comprising valve structure disposed in proximity to the port and including a support and a valve carried

by the support for movement between port-opening and port-closing positions, valve opening and closing means including first and second pressure-responsive areas acting in opposite directions on the valve and effective upon changes in pressure differential therebetween to determine the direction of valve movement, a valve chamber separated from the power chamber at least in part by the valve and containing the second area, and magnetic means releasably holding the valve closed and operative by magnetic attraction and holding forces to resist valve-opening forces below, and to suddenly release the valve at, a predetermined value, whereby the magnetic attraction diminishes, said first area being exposed to inlet chamber pressure and effective when the pressure differential exists in its favor to incur a valve-opening force up to said value for overcoming the magnetic holding force and thus to suddenly open the port and to move the valve in an amount where the magnetic attraction is relatively weak and said second area combining with the magnetic attraction to return the valve in an amount within the range of stronger magnetic attractive forces to effect reclosing of the valve when the pressure differential in favor of the first area is at least partly removed; and valve cycling means operative when the valve closes to discharge the valve chamber to a pressure lower than that of the inlet chamber to cause a pressure differential to exist in favor of valve opening and operative when the valve opens to connect the valve chamber to the inlet chamber and thus



to change the pressure differential in favor of valve closing.

**22.** The invention defined in claim **2**, in which: said valve cycling means has a passage system which includes a first passage portion leading from the valve chamber to the inlet chamber for pressurizing said second area when the valve is open and a separate second passage portion leading from said valve chamber to said lower pressure, a check valve opening said first passage portion to the effects of inlet chamber pressure and closing against the discharge of the valve chamber to the power chamber whereby said area is compelled to lead to said lower pressure by said second passage portion, the releasable means comprises magnetic means, and biasing means acts on the valve in a closing direction when the valve is open.


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UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,216,328 November 9, 1965

Axel H. Peterson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 44, for "700" read -- .700 --.

Signed and sealed this 17th day of May 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents