March 13, 1973 P. J. JOUSSON ET AL 3,720,486

HYDRAULIC ACTUATORS

Filed Sept. 21. 1970 3 Sheets-Sheet 1

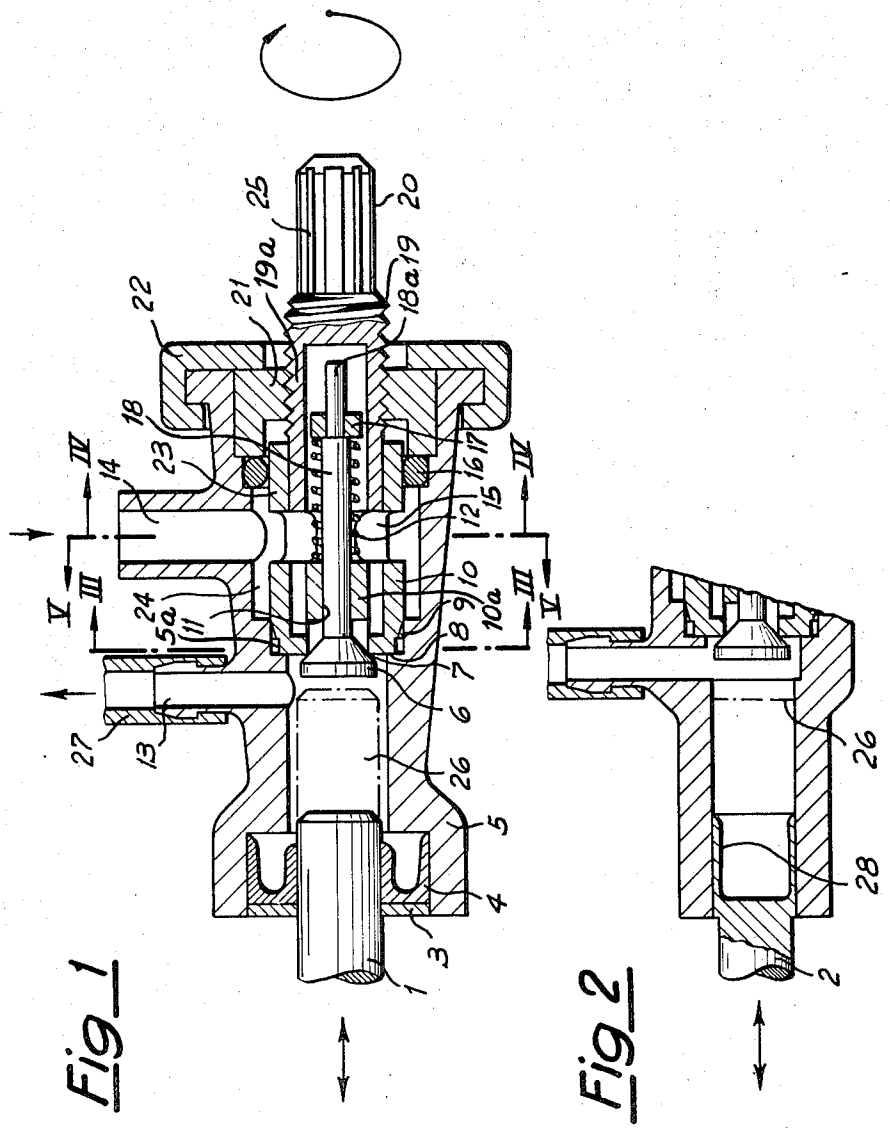

Fig 1

Fig 2

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HYDRAULIC ACTUATORS

Filed Sept. 21. 1970 3 Sheets-Sheet 2

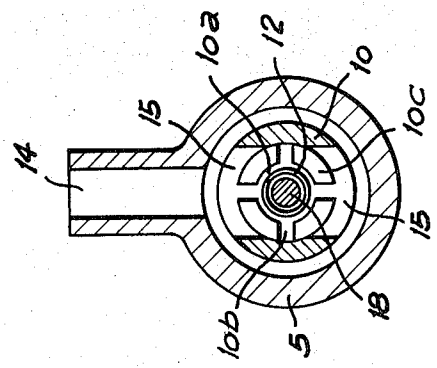

Fig 5

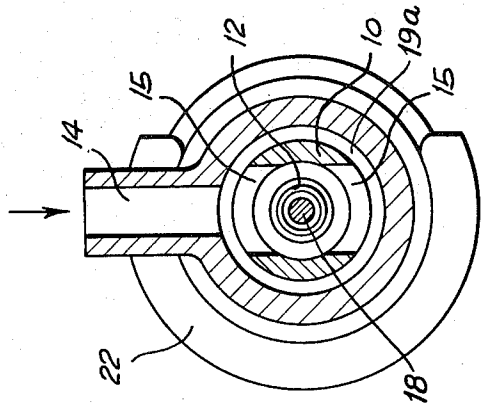

Fig 4

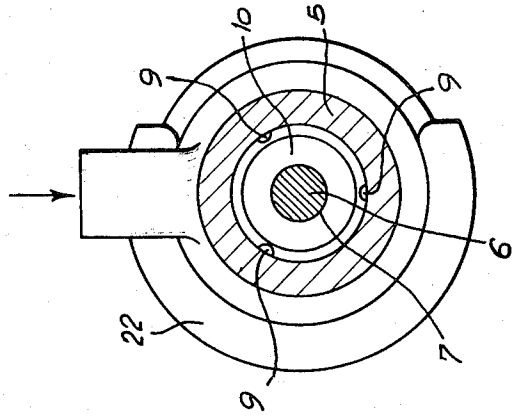

Fig 3

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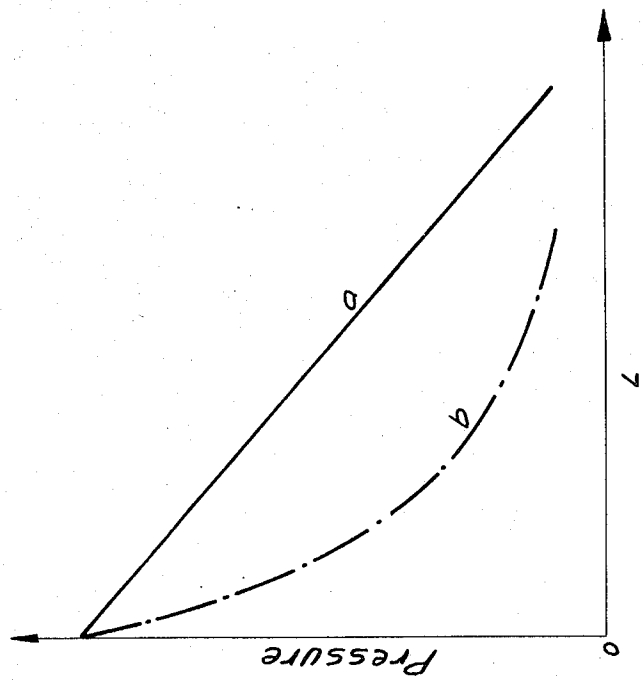

Fig 7

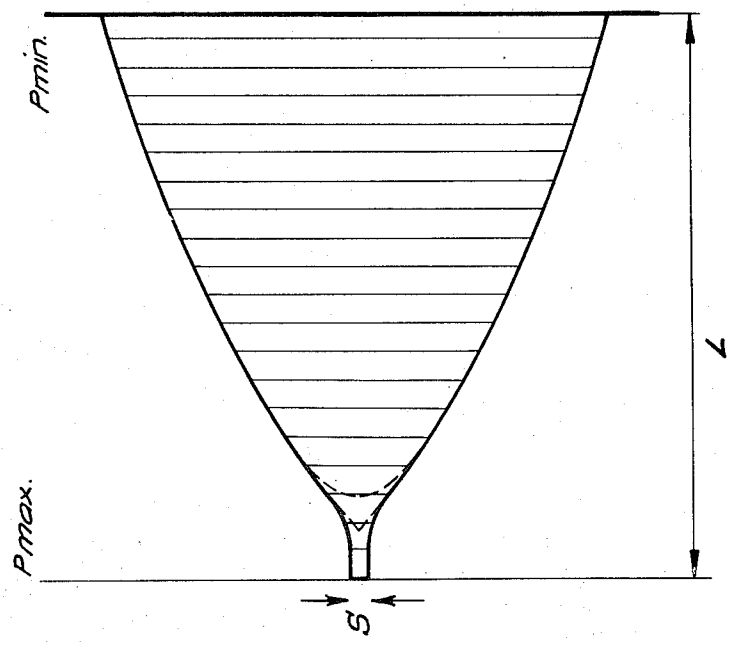

Fig 6

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3,720,486

HYDRAULIC ACTUATORS

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Claims priority, application Switzerland, Sept. 19, 1969, 14,239/69
Int. Cl. F04b 21/02
U.S. Cl. 417—440 6 Claims

ABSTRACT OF THE DISCLOSURE

An hydraulic actuator for supplying liquid pressure pulses to a hand appliance for body care comprises a cylinder and reciprocating piston forming a working chamber, an outlet passage connected to the working chamber, an inlet chamber connected to the working chamber through an inlet valve, and pressure regulating means for bypassing a portion of the liquid to the inlet chamber on the pressure stroke of the piston. The pressure regulating means includes a valve holder adjustably mounted in the inlet chamber and movable toward and away from an opening in the working chamber opposite the piston, and the inlet valve is mounted therein inside the annular region of the valve holder which closes the opening. Tapered notches at the front end of the valve holder cooperate with the housing to provide bypass passages of progressively increasing cross-sectional area as the valve holder is moved away from the opening, and are designed to provide a linear reduction in liquid pressure in the outlet passage.

BACKGROUND OF THE INVENTION

The present invention relates to hydraulic actuator units which can be used either as pump units for connection to hygiene devices, for example, hydraulic motor driven toothbrushes, water jet devices for eliminating food residues from interdental spaces and gum massaging devices, or hydraulic transmitter devices.

In co-pending application, Ser. No. 736,440, filed on June 12, 1968 now Pat. No. 3,536,065, issued Oct. 27, 1970, an apparatus for body care is described which includes a pump unit having a liquid reservoir, and an electric motor for driving the pump unit. The pump unit includes a reciprocating piston which is driven by the electric motor. The piston is slidable within a cylindrical part of a working chamber formed in the body of the pump unit and water is admitted to the working chamber from a reservoir and an inlet chamber, through an inlet valve. Movement of the piston in one direction permits water to flow from the inlet chamber, via the inlet valve, into the working chamber. Movement of the piston in the reverse direction causes the inlet valve to close and the water to be delivered under pressure to a supply conduit.

The pump unit further includes a pressure regulating device which includes an orifice which permits water under pressure from the working chamber to return to the inlet chamber. The orifice is controlled by means of a plunger faced with a resilient insert. By moving the plunger in one sense a small by-pass passage is opened and the pump unit therefore delivers water at a lower pressure through the supply conduit.

In the aforesaid application the pump unit supplies liquid pressure pulses to a unitary hand appliance capable of operation either as an hydraulic toothbrush or as a water jet. The hand appliance includes a piston-type hydraulic motor for driving a toothbrush attachment, or other attachments, and a conduit for supplying the pressure pulses to a water jet attachment. A valve is provided which is actuable to yield either type of operation.

Other similar pump units are known in the art for supplying liquid pressure pulses to separately attachable hand appliances, one of which is a water jet appliance and the other a toothbrush appliance.

In both the pump unit described in co-pending application, Ser. No. 736,440, and in the other known pump unit, there is no discharge valve for controlling the flow of liquid from the working chamber to the supply conduit. Both pump units rely on the supply conduit having an adequate length and cross-sectional dimension to prevent sucking back of liquid into the working chamber on the suction stroke of the piston during water jet operation.

Since there is no discharge valve, and because of the inertia characteristics of the flow of liquid, during water jet operation there is a tendency for the liquid to continue to flow after the piston has reached its position of maximum compression and had started to return on a suction stroke. Thus, more water is discharged from the pump than the amount displaced by the piston.

One disadvantage of these pump units, is that the inlet valve is positioned entirely in the working chamber, that is, the space between the piston and the supply conduit. This gives rise to a high proportion of dead space which adversely effects the efficiency of the pump unit and is conducive to the formation of air bubbles.

Further, the presence of a by-pass passage as described in my co-pending application, Ser. No. 736,440 is also conducive to the formation of air bubbles.

Air bubbles can cause difficulties when starting the pump units and may, in fact prevent starting altogether. Sometimes the air bubbles can be dispersed by manipulating the pressure regulating device to bleed or deaerate the pump unit but this is time consuming and not always successful.

Air bubbles are particularly troublesome when the hydraulic actuator is used to drive an hydraulic motor in a hand appliance, and an accurate transmission of a displacement is required.

A second disadvantage found in both the above described known devices is the difficulty encountered in accurately regulating the pressure of the liquid discharge from the pump units.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide a hydraulic actuator which is small and compact and in which the dead space is reduced to a minimum and the formation of air bubbles reduced.

It is a further object of the present invention, to provide a hydraulic actuator which includes means for accurately regulating the pressure of liquid discharged from the actuator. The means includes a by-pass arrangement, displacement of which, in the body of the actuator, causes a change in the pressure of the liquid discharged from the actuator, the displacement and the change in pressure having a linear relationship.

A still further object of the present invention is the provision of an hdraulic actuator, the construction and assembly of which is very simple.

The present invention employs a reciprocating piston mounted in a cylinder to form a working chamber, with an outlet passage connected to the working chamber for supplying liquid pressure pulses to a hand appliance for body care. In accordance with the invention, an opening to the working chamber is provided opposite the piston, and the inlet chamber is on the opposite side of the opening from the piston. The pressure regulating means includes a valve holder adjustably mounted in the inlet

chamber for movement toward and away from the opening to bypass a portion of the liquid to the inlet chamber on the pressure stroke of the piston. The front of the valve holder has an annular region adapted to abut a corresponding annular region around the opening to prevent liquid flow thereby in the forward position of the valve holder, thereby yielding maximum pressure pulses in the outlet passage. As the valve holder is moved away from the opening, there is a progressively increasing liquid flow from the working chamber back to the inlet chamber on the pressure stroke of the piston, thereby allowing a progressive reduction in the pressure of pulses in the outlet passage.

An inlet valve is mounted in the valve holder with the valve head on the working chamber side of the valve holder and cooperates with a valve seat on the front of the valve holder. The valve head and valve seat are inside the annular region of the pressure regulating means. With this arrangement, dead space in the working chamber is largely eliminated, so that room for the formation of air bubbles is largely eliminated. Further, since the annular region of the pressure regulating means is around the inlet valve, any air bubbles which may form near the annular region when the pressure regulating means is closed are carried away by water flowing by the inlet valve head on each suction stroke of the piston.

Preferably the inlet valve has a valve stem carrying the valve head, and the valve stem is mounted inside the valve holder and movable in the direction of movement of the piston. Thus the forces acting on the valve head and stem are in the direction of movement thereof, so that bending forces are largely avoided, thereby avoiding excessive wear and promoting reliable operation over a long period of time even though plastic materials are used to reduce cost.

Advantageously the front of the valve holder and the adjacent portion of the valve housing have closely-spaced longitudinally extending surfaces with a plurality of tapered notches in one of the surfaces shaped to provide corresponding passages of progressively increasing cross-sectional area for fluid flow from the working chamber to the inlet chamber as the valve holder is moved away from the opening to the working chamber, thereby producing a gradual change in pressure of the outlet pulses as the pressure regulating means is adjusted. Preferably the cross-sectional area of the tapered notches is predetermined to yield a reduction in outlet pulse pressure which varies linearly with the movement of the valve holder away from the opening. This greatly facilitates adjustment of the pressure to suit the user's desires.

DESCRIPTION OF THE FIGURES OF THE DRAWINGS

An embodiment of the invention will now be described, by way of example, reference being made to the figures of the accompanying drawings in which:

FIG. 1 is a longitudinal section through a hydraulic actuator according to the present invention;

FIG. 2 is a partial longitudinal section illustrating a modification of the hydraulic actuator of FIG. 1;

FIG. 3 is a transverse cross-section on the line III—III of FIG. 1;

FIG. 4 is a transverse cross-section on the line IV—IV of FIG. 1;

FIG. 5 is a transverse cross-section on the line V—V of FIG. 1;

FIG. 6 is a graph showing the progression of the cross-sectional area of the by-pass section according to the regulation position; and

FIG. 7 is a graph which illustrates the variations of pressure according to displacements of the pressure regulator of a known hydraulic actuator and a hydraulic actuator according to the invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

As shown in FIG. 1, a hydraulic actuator for connection to a hygiene appliance such as a toothbrush, includes a generally tubular body **5** having a through bore and two passageways **13**, **14** extending through a side wall of the body **5**. Passageway **14** is an inlet passageway and communicates with a liquid reservoir (not shown) and passageway **13** is an outlet passageway and is connected, by means of a conduit **27**, to a hygiene appliance (not shown) for example, a hydraulic motor driven toothbrush.

At the left hand end of the body **5**, as seen in FIG. 1, the through bore includes a cylindrical working chamber **26** in which reciprocates a piston **1** driven by any known means (not shown). A seal **4** is mounted around the piston **1** in a recess formed at said left hand end, and a guide plate **3** encloses the seal **4** in the recess. The guide plate **3** also centers the piston **1** in the working chamber **26**.

At its opposite end, the body **5**, has an inlet chamber **24** which is enlarged to receive an insert **21** having a central threaded hole. The insert **21** seats on a shoulder in the inlet chamber **24** and has an end face flush with the end of the body **5**. A retaining clip **22** of resilient material engages over a flange surrounding the opposite end of the body **5**, that is, the right hand end of body **5** and engages the end face of the insert **21**.

An adjustable pressure regulating member and valve holder **19** is screwed through the central threaded hole in the insert **21**. The member **19** includes a first part **19***a* having a central bore, and a knob **20** extending outwardly from the end of the body **5**. The knob **20** has flutes **25** to assist in the turning of the member **19**. An end portion of the first part **19***a* carries a second part in the form of a sleeve **23** for movement therewith. The sleeve **23**, as seen in FIGS. 1 and 5 is generally cylindrical and is open at the end carried by the first part **19***a* and formed with an inwardly directed flange at the opposite end. The flange defines a hole and the outer peripheral edge of the flange is formed as a seating **7** for a valve head **6** of a valve member. Arms **10***b* extend radially inwardly from a part **10** of the sleeve **23** for supporting a bearing part **10***a*. The valve member has a stem **18** which extends through and is supported by bearing part **10***a*. Opposed apertures **15** are formed in the side walls of the sleeve **23**, which apertures **15** are in general alignment with the inlet passageway **14**.

A shoulder **17** is rigidly attached to the valve stem **18** and a spring **12** is arranged between the shoulder **17** and an end face of the bearing part **10***a* to bias the valve head **6** against the seating **7**. A seal **16** is arranged over the end of the sleeve **23** adjacent the insert **21**.

As will be noted from FIG. 1, an annular region of the front of sleeve **23** forming part of the valve holder abuts a corresponding annular region of the shoulder **8** of the body **5** which forms part of the pump housing, and hence closes the opening in the wall of the working chamber **26** opposite the piston **1**. Thus no liquid can pass thereby. Rotation of the valve holder by knob **20** allows the front of sleeve **23** to be moved away from shoulder **8**. The periphery of the front end of sleeve **23** has a longitudinally-extending surface which is closely adjacent a corresponding longitudinally-extending surface of body **5**. As shown in FIGS. 1 and 3, the logitudinally-extending surface at the front of sleeve **23** has a plurality of tapered notches **9** which increase in cross-section toward the front of sleeve **23**.

In the position shown, the small ends of the notches are in engagement with the adjacent surface of body **5**. However, as the valve holder is moved to the right by rotating knob **20**, the effective cross-sectional area of the notches progressively increases, thereby allowing a progressively increasing liquid flow thereby from the working chamber **26** to the inlet chamber **24** on the pressure strokes of the piston **1**. Thus the pressure of the liquid pulses in outlet passage **13** is gradually reduced as the valve holder is moved toward the right. Advantageously the notches **9** are shaped so that the reduction in pressure

in the outlet passage 13 varies linearly with movement of the valve holder sleeve 23 away from the opening in the working chamber 26. This will be explained further in connection with FIGS. 6 and 7.

It will also be noted from FIG. 1 that there is very little dead space in which air bubbles can accumulate. With the pressure regulator closed, as shown, there is an annular space around the valve head 6 in which air bubbles may tend to accumulate. However, with the valve head 6 on the working chamber side of the valve seat 7, the flow of water around the valve head on the suction strokes of the piston tends to wash out air bubbles which may form in this annular space so that excessive accumulation of air in this space is prevented.

In operation, the piston 1 is reciprocated in the working chamber 26 such that, when it moves to the left as shown in FIG. 1, liquid is drawn through inlet passageway 14 into the inlet chamber 24 through apertures 15 into the valve holder and then into the working chamber 26. Movement of the piston 1 in the reverse or compression sense, causes the valve head 6 to seat on the seating 7 and the liquid in the working chamber 26 to be discharged under pressure through outlet passageway 13.

In order to regulate the pressure at which the liquid is discharged, from the body 5, knob 20 can be turned to adjust the position of member 19 in the body 5. Adjustment of member 19 permits to a greater or lesser extent a by-pass to be formed between the shoulder 8 and the end face of sleeve 23 carried by member 19. By increasing the distance between the shoulder 8 and the end face of the sleeve 23, when the piston is making a compression stroke, some liquid will flow from the working chamber 26 through the space between the shoulder 8 of body 5 and the end face of sleeve 23 and then through notches 9, thereby reducing the pressure of the liquid being discharged through the outlet passageway 13.

FIG. 2 illustrates a modification of the piston of the hydraulic actuator, in which the piston 2 consists of a semi-elastic plastics material having a circular lip 28 which is arranged in a liquid tight manner in the working chamber 26. With this piston it is possible to eliminate the seal 4 and guide plate 3 described with reference to FIG. 1.

FIG. 6 is a graph showing the progressive change in the cross-sectional area of the pressure regulating arrangement according to the axial position L of the sleeve 23. The line P_{max} designated the closed position of the pressure regulator and P_{min} the fully open position. It can be seen that from the starting (closed) position of the sleeve 23, the area is constant for about 10% of its displacement then the area change becomes practically linear for about 15% of the displacement and then becomes hyperbolic or exponential according to conditions. Clearly, the number of tapered notches 9 in the end face of the sleeve 23 can vary and some experimentation as to the precise shape of the taper may have to be performed under particular conditions to obtain a linear regulation of the pressure.

FIG. 7 is a graph which illustrates the decrease of pressure P in the working chamber 26 according to the axial position L of the pressure regulator member 19. The straight line *a* represents the linear function of the regulation obtained according to a pressure regulator of the present invention. Curve line *b* represents the function obtained by a known pressure regulator. As will be noted, curve *b* shows a rapid decrease in pressure as the regulator is moved from its closed position, thereby making the adjustment quite difficult in the higher pressure region. On the other hand, curve *a* shows a much more gradual change, thereby facilitating the obtaining of a desired mid-range pressure.

The above described embodiment is a simple hydraulic actuator of small dimensions which can be assembled quickly and easily without use of special tools or skilled staff. Throughout the specification reference has been made to the use of the hydraulic actuator as a pump unit, but clearly and as well known in the art, the hydraulic actuator can be used as a transmitter device, for transmitting linear displacements.

An advantage of the present embodiment is that it permits the regulation of liquid under a pressure in a simple linear and reliable manner, this is what is usually required when the actuator is used with hygiene appliances.

Further, by reducing the dead space to an absolute minimum, the formation of air bubbles is substantially reduced and is a technical advance over known hydraulic actuators.

The hydraulic actuator can be manufactured from plastics material.

We claim:

1. An hydraulic actuator for supplying liquid pressure pulses to a hand appliance for body care which comprises
   (a) a housing having a cylinder and a reciprocating piston mounted therein forming a working chamber,
   (b) an outlet passage connected to said working chamber for supplying liquid pressure pulses to a said hand appliance,
   (c) said outlet passage being free of a discharge valve,
   (d) an opening in said housing to said working chamber opposite said piston,
   (e) an inlet chamber in said housing on the opposite side of said opening from said piston,
   (f) manually-operated pressure regulating means comprising a valve holder adjustably mounted in said inlet chamber for progressive adjustment toward and away from said opening and for establishing an dmaintaining a fixed spacing between said valve holder and opening when manually adjusted thereto and thereby bypass a selectable portion of the liquid in said working chamber to said inlet chamber on the pressure stroke of said piston,
   (g) the front of said valve holder having an annular region adapted to abut a corresponding annular region of said housing around said opening to prevent liquid flow thereby in the forward position of the valve holder and to allow a progressively increasing liquid flow thereby as the valve holder is moved away from the opening,
   (h) an inlet valve mounted in said valve holder having a valve head on the working chamber side of the valve holder and a cooperating valve seat on the front of the valve holder,
   (i) said valve head and valve seat being inside said annular region so that liquid flow through the inlet valve on the suction stroke of the piston washes through the region adjacent the front of the valve holder and said opening to prevent accumulation of air in said region in the closed position of said pressure regulating means,
   (j) and means for resiliently biasing said valve head toward said valve seat.

2. An hydraulic actuator for supplying pressure pulses to a hand appliance for body care which comprises
   (a) a housing having a cylinder and a reciprocating piston mounted therein forming a working chamber,
   (b) an opening in said housing to said working chamber opposite said piston,
   (c) an inlet chamber in said housing on the opposite side of said opening from said piston,
   (d) an outlet passage connected to the side of said working chamber adjacent said opening for supplying liquid pressure pulses to a said hand appliance,
   (e) said outlet passage being free of a discharge valve,
   (f) manually-operated pressure regulating means comprising a valve holder threadedly mounted in said inlet chamber for progressive adjustment toward and away from said opening and for establishing and maintaining a fixed spacing between said valve holder and opening when manually adjusted thereto and thereby bypass a selectable portion of the liquid

in said working chamber to said inlet chamber on the pressure stroke of said piston,

(g) the front of said valve holder having an annular region adapted to abut a corresponding annular region of said housnig around said opening to prevent liquid flow thereby in the forward position of the valve holder and to allow a progressively increasing liquid flow thereby as the valve holder is moved away from the opening,

(h) an inlet valve including a valve head and valve stem mounted in said holder with the valve head on the working chamber side of the front of the valve holder and the valve stem inside the valve holder and movable in the direction of movement of said piston,

(i) a valve seat on the front of the valve holder cooperating with said valve head and a spring mounted within the valve holder for biasing the valve head toward the valve seat,

(j) said valve head and valve seat being inside said annular region so that liquid flow through the inlet valve on the suction stroke of the piston washes through the region adjacent the front of the valve holder and said opening to prevent accumulation of air in said region in the closed position of said pressure regulating means.

3. An hydraulic actuator for supplying liquid pressure pulses to a hand appliance for body care which comprises

(a) a housing having a cylinder and a reciprocating piston mounted therein forming a working chamber,

(b) an opening in said housing to said working chamber opposite said piston,

(c) an inlet chamber in said housing on the opposite side of said opening from said piston,

(d) an outlet passage connected to the side of said working chamber adjacent said opening for supplying liquid pressure pulses to a said hand appliance,

(e) pressure regulating means comprising a valve holder threadedly mounted in said inlet chamber for movement toward and away from said opening to bypass a portion of the liquid in said working chamber to said inlet chamber on the pressure stroke of said piston,

(f) the front of said valve holder having an annular region adapted to abut a corresponding annular region of said housing around said opening to prevent liquid flow thereby in the forward position of the valve holder and to allow a progressively increasing liquid flow thereby as the valve holder is moved away from the opening,

(g) said housing and the front end of said valve holder having closely-spaced longitudinally-extending surfaces with a plurality of tapered notches in one of said surfaces shaped to provide corresponding passages of progressively increasing cross-sectional area for fluid flow from the working chamber to the inlet chamber as the valve holder is moved away from said opening,

(h) an inlet valve including a valve head and valve stem mounted in said holder with the valve head on the working chamber side of the front of the valve holder and the valve stem inside the valve holder and movable in the direction of movement of said piston,

(i) a value seat on the front of the valve holder cooperating with said valve head and a spring mounted within the valve holder for biasing the valve head toward the valve seat,

(j) said valve head and valve seat being inside said annular region.

4. An hydraulic actuator in accordance with claim 3

in which the progressively increasing cross-sectional area of said tapered notches is predetermined to yield a reduction in pressure of the liquid discharged through said outlet passage which varies linearly with the movement of said valve holder away from said opening.

5. An hydraulic actuator for supplying liquid pressure pulses to a hand appliance for body care which comprises

(a) a housing having a cylinder and a reciprocating piston mounted therein forming a working chamber,

(b) an outlet passage connected to said working chamber for supplying liquid pressure pulses to a said hand appliance,

(c) an opening in said housing to said working chamber opposite said piston,

(d) an inlet chamber in said housing on the opposite side of said opening from said piston,

(e) pressure regulating means comprising a valve holder adjustably mounted in said inlet chamber for movement toward and away from said opening to bypass a portion of the liquid to the inlet chamber on the pressure stroke of said piston,

(f) the front of said valve holder having an annular region adapted to abut a corresponding annular region of said housing around said opening to prevent liquid flow thereby in the forward position of the valve holder and to allow a progressively increasing liquid flow thereby as the valve holder is moved away from the opening,

(g) said housing and the front end of said valve holder having closely-spaced longitudinally-extending surfaces with a plurality of tapered notches in one of said surfaces shaped to provide corresponding passages of progressively increasing cross-sectional area for fluid flow from the working chamber to the inlet chamber as the valve holder is moved away from said opening,

(h) an inlet valve mounted in said valve holder having a valve head on the working chamber side of the valve holder and a cooperating valve seat on the front of the valve holder,

(i) said valve head and valve seat being inside said annular region, and

(j) means for resiliently biasing said valve head toward said valve seat.

6. An hydraulic actuator in accordance with claim 5 in which the progressively increasing cross-sectional area of said tapered notches is predetermined to yield a reduction in pressure of the liquid discharged through said outlet passage which varies linearly with the movement of said valve holder away from said opening.

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