United States Patent [19]

Johnston

[11] **3,854,706**

[45] **Dec. 17, 1974**

[54] **SHOCK ABSORBING APPARATUS FOR HEAVY LOADS**

[75] Inventor: **James G. Johnston,** Willits, Calif.

[73] Assignee: **Stanray Corporation,** Chicago, Ill.

[22] Filed: **Mar. 16, 1973**

[21] Appl. No.: **341,812**

[52] **U.S. Cl.** ..... **267/116,** 267/139, 267/65 R

[51] **Int. Cl.** **F16f 5/60**

[58] **Field of Search** ..... 267/139, 116, 65 R

[56] **References Cited**

UNITED STATES PATENTS

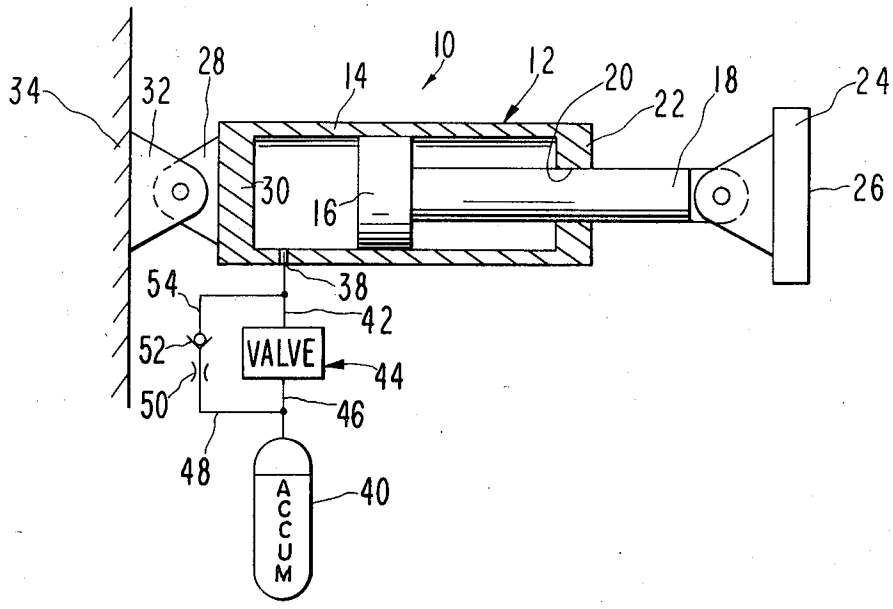
3,433,474	3/1969	Pirel	267/65
3,494,606	2/1970	Hanchen	267/116

Primary Examiner—James B. Marbert

[57] **ABSTRACT**

Apparatus for absorbing the shock of a relatively large, movable load, such as a ship striking a dock or the like. The apparatus includes a loadreceiving buffer comprised of a fluid piston and cylinder assembly, the buffer being in fluid communication with a hydropneumatic accumulator through first and second fluid flow paths. When a force is exerted on the buffer, fluid flows therefrom through one of said paths and part of the kinetic energy is stored in the accumulator with the greater portion dissipated as heat. The buffer is restored to its initial position by fluid flow from the accumulator to the buffer along the second path. The system operates to assure that the buffer will exert a substantially constant reactive force regardless of displacement to thereby assure dissipation of the kinetic energy with an efficiency approaching 100 percent and with a minimum storage of potential energy.

12 Claims, 3 Drawing Figures



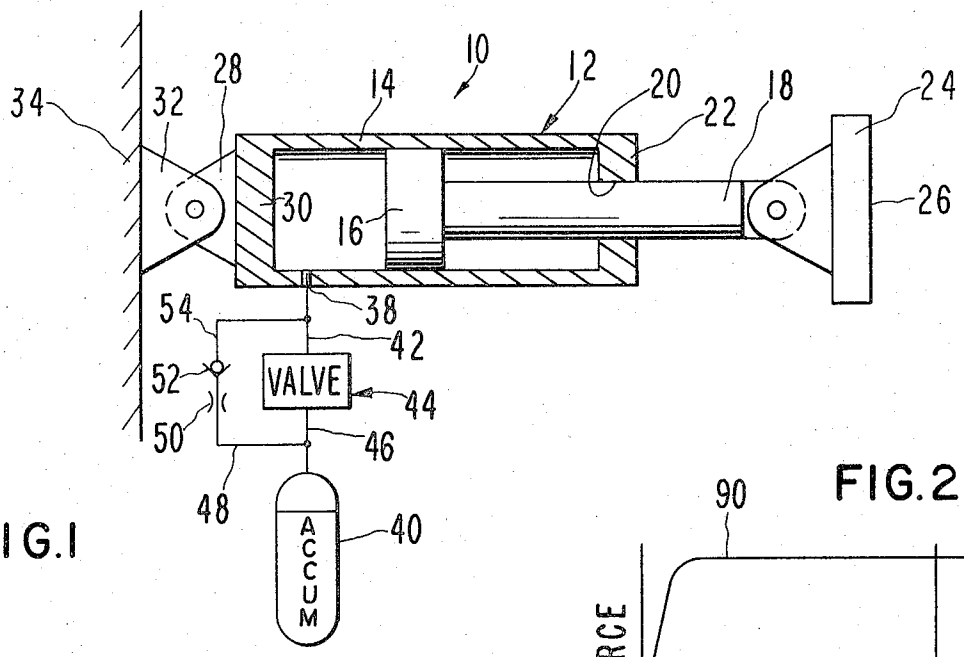
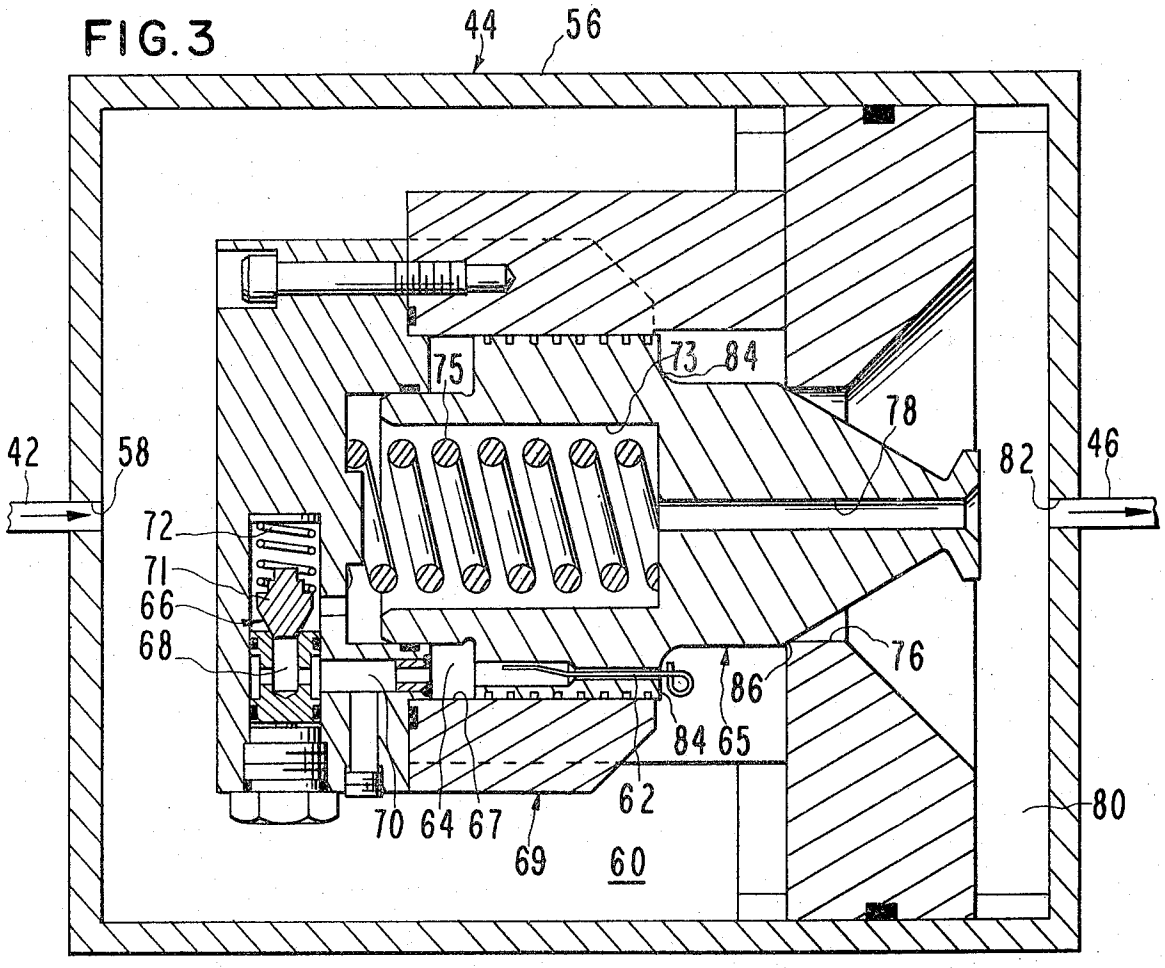


FIG.1

FIG.2

FIG.3



SHOCK ABSORBING APPARATUS FOR HEAVY LOADS

This invention relates to improvements in shock absorbing devices of the type for dissipating or storing the energy due to the deceleration of large masses, such as the engagement of a large ship with a dock structure.

BACKGROUND OF THE INVENTION

When a large ship is docked, it oftentimes exerts large forces on the dock structure. Some such loads on the dock structure can be large enough to cause structural damage thereto. It is necessary, therefore, to dissipate the kinetic energy of the ship efficiently with a minimum of structural damage.

Generally, there are two types of devices now in use for handling the shocks caused by ships being docked. The first is a rubber spring which can be of any one of a number of different configurations. However, this type of device has a basic drawback, namely, that the spring absorbs and stores potential energy with an efficiency generally not exceeding **60** percent. As the deflection or deformation of the spring increases, the reactive force of the spring increases proportionately. Therefore, the system is inefficient because the reactive force is directly related to the deflection.

Another type of conventional shock absorbing device is a hydraulic unit having either a fixed orifice or constantly decreasing orifice. The fixed orifice unit is similar to the spring type mentioned above with respect to efficiency because, if the velocity of the mass reduces during dissipation of its kinetic energy, the resistance or reactive force reduces accordingly. In addition, the resistance at any time during such energy dissipation is directly related to velocity. This means that too large a reactive force can be exerted on the mass at high velocity or too small a force can be exerted on it at low velocity, thereby inefficiently dissipating the energy.

The unit with the constantly decreasing orifice is an improvement over the unit having the fixed orifice because, if the velocity of the mass decreases during the dissipation of the kinetic energy, the orifice size also decreases, thereby theoretically maintaining a constant reactive force on the mass. However, the drawbacks of this type includes the fact that the unit could still exert too large a force on the mass or, if the orifice is sized for the greatest velocity which is to be expected, then, in practice, the velocity will be somewhere below this value; thus, the reactive force exerted on the mass will be less than is needed. Therefore, the energy dissipation will be, again, inefficient. In both the foregoing cases, the efficiency of the system is directly related to the velocity of the mass.

SUMMARY OF THE INVENTION

The apparatus of the present invention avoids the problems associated with the use of conventional structures of the type described because it operates to maintain a constant resistance or reactive force on a moving mass regardless of the velocity thereof. This reactive force or resistance is predetermined and based upon the force which can be safely applied to the structure defining such mass. The apparatus includes a hydraulic buffer in which resistance or a reactive force developed thereby is directly related to a hydraulic pressure therein. Moreover, the apparatus includes means defining an annular orifice which is adjusted automatically

to maintain a constant pressure drop across the buffer regardless of the velocity of the moving mass against which the reactive force is exerted.

The system is operable to dissipate a major portion of the energy of the mass with only a small portion of the energy being stored. The resistance or reactive force of the apparatus is substantially constant not only with respect to velocity but with respect to the position of the displacement stroke of the buffer. Also, the apparatus operates to absorb the maximum amount of energy throughout its entire stroke.

The apparatus further operates to restore the buffer to an initial operating position by utilizing the stored energy to reset the buffer. Thereafter, the apparatus is ready for receiving another shock applied by a moving mass.

The primary object of this invention is to provide an improved shock absorbing apparatus suitable for dissipating the kinetic energy of large masses wherein the apparatus operates to provide a substantially constant reactive force or resistance to a moving mass while dissipating its kinetic energy, with the force being independent of velocity and displacement of the moving parts of the apparatus during the energy dissipation interval.

Another object of this invention is to provide an apparatus of the type described wherein the apparatus includes components which effectively dissipate the kinetic energy of a moving mass yet allows a small portion of the energy to be stored so that such stored energy can be used to reset the apparatus to its initial operating condition after the kinetic energy of the mass has been fully dissipated.

Still another object of this invention is to provide apparatus of the aforesaid character wherein a load-receiving buffer is coupled by valve means to a fluid accumulator so that energy is dissipated in the valve means and the connecting lines and is partially stored in an accumulator so that the energy will be effectively dissipated yet the stored energy of the accumulator can be used to reset the buffer to its initial position, ready to receive the shock loads of another incoming mass.

Other objects of this invention will become apparent as the following specification progresses, reference being had to the accompanying drawing for an illustration of the invention.

In the drawing:

FIG. **1** is a schematic view of the apparatus of this invention, showing the force-receiving buffer thereof in the form of a fluid piston and cylinder assembly coupled by valve means to a fluid accumulator;

FIG. **2** is a graphic view of the force-displacement characteristic of the buffer; and

FIG. **3** is a cross-sectional view of an embodiment of the valve used to interconnect the buffer and the accumulator.

The apparatus of this invention is broadly denoted by the numeral **10** and is illustrated in FIG. **1.** Apparatus **10** includes a buffer **12** having a cylinder **14** provided with a piston **16** shiftably mounted therewithin between a pair of opposed end walls **22** and **30** of the cylinder. A shaft **18** secured to piston **16** extends through an opening **20** in end wall **22** and projects outwardly therefrom. A pad **24** is pivotally or otherwise coupled to the outer end of shaft **18** and is provided with a flat, outer surface **26** which is adapted to be engaged by a

moving structure defining a mass whose kinetic energy is to be dissipated by apparatus **10**. Cylinder **14** has plate means **28** coupled to end wall **30** for attachment in any suitable manner to a mounting plate **32** on a rigid support **34**, such as a wall, dock or the like.

Cylinder **14** has a chamber **36** between piston **16** and end wall **30**. This chamber is adapted to contain a hydraulic fluid and varies in volume in response to the movement of piston **16** relative to cylinder **14**. The cylinder has a fluid flow passage **38** through its sidewall in communication with chamber **36**.

A fluid accumulator **40** also forms a part of apparatus **10**. Accumulator **40** has an inlet which is coupled by a first flow line **42**, a valve **44** and a second flow line **46** to passage **38**. Valve **44** operates to allow fluid flow from chamber **36** to accumulator **40** when piston **16** moves to the left when viewing FIG. **1**, i.e., during a displacement stroke of buffer **12**. Thus, lines **42** and **46** and valve **44** form a first fluid flow path between the buffer and the accumulator.

A second fluid flow path is provided between buffer **12** and accumulator **40** in bypassing relationship to valve **44**. This second path includes a fluid flow line **48** coupled to a flow line **46**, a flow control valve device **50**, and a check valve **52** of the type which allows flow of fluid only in a direction from the accumulator to the buffer. A flow line **54** connects check valve **52** with line **42**. Flow control valve device **50** can be eliminated if it is not considered necessary.

Valve **44** operates to maintain a constant fluid pressure within chamber **36** regardless of the velocity of piston **16** and regardless of its position relative to cylinder **14**. To this end, valve **44** has an outer housing **56** (FIG. **3**) provided with an inlet opening **58** coupled to fluid flow line **42**. Fluid from chamber **36** and line **42** enters housing **56** and passes into an outer chamber **60**, passing thereafter through an orifice **62** in an annular extension **63** of a shiftable valve member **65** shiftably carried within a bore **67** in a fixed body **69** within housing **56**.

Fluid passing through orifice **62** enters a chamber **64** in body **69**. Chamber **64** is in fluid communication with a pilot relief valve **66** through passages **68** and **70**. Valve **66** has a shiftable valve member **71** which is biased toward a closed position by a coil spring **72**. The fluid passing through valve **66** enters the central bore **73** in extension **63** of valve member **65**, the latter being biased by a coil spring **75** into closing relationship to an outlet orifice **76** in body **69**. Valve member **65** also has a fluid passage **78** therethrough which permits any excess hydraulic fluid to pass into a region **80** exteriorly of body **69** and communicating with line **46** through an outlet opening **82**.

As pilot relief valve member **71** opens, there is a pressure drop between chambers **60** and **64**, the higher pressure being in chamber **60**. Such higher pressure thereby exerts a force on the annular face **84** of valve member **65**, thereby causing the latter to be moved to the left when viewing FIG. **3** and out of engagement with the valve seat **86** at the entrance of orifice **76**. Fluid flowing into chamber **60** can then pass through orifice **76** and out of valve **44** to line **46**.

During use, apparatus **10** is mounted on support **34** such as in the manner shown in FIG. **1**. Piston **16** will have an initial position within cylinder **14** by virtue of a predetermined volume of hydraulic fluid, such as oil, in chamber **36**. Valve **44** will, of course, be closed because valve member **65** will close orifice **76** under the bias force of spring **75**. Chamber **60** of valve **44** will also contain fluid by virtue of its communication with chamber **36**.

When a mass strikes pad **24**, shaft **18** will be forced into the cylinder, causing piston **16** to move to the left when viewing FIG. **1**. This will cause an increase in fluid pressure in chambers **36** and **60**. Chamber **64**, also in fluid communication with chamber **60**, will experience an increase in pressure until the pressure increase exceeds the bias force of spring **72**, whereupon valve **66** will open, causing the fluid pressure in chamber **64** to drop with respect to that in chamber **60**. Thus, the unbalanced force due to the variation in fluid pressures in chambers **60** and **64** will cause valve member **65** to unset with respect to valve seat **86**, thereby opening the fluid passage defined by orifice **76**. Fluid will then flow from chamber **60** through orifice **76**, into region **80**, through line **46** to accumulator **40**. The accumulator will then be pressurized by the incoming fluid thereto so as to store a portion of the energy in the form of fluid pressure, such stored energy representing a portion of the energy of the mass striking pad **24**.

Pilot relief valve **66** and orifice **62** are selected as to size so that a relatively constant pressure is maintained in chamber **60** regardless of velocity or stroke of piston **16**. For instance, if the fluid pressure commences to rise in chamber **60**, valve member **62** shifts to the left when viewing FIG. **3**, to open or increase the effective opening of orifice **76**, thereby causing a decrease in the pressure in chamber **60** and ultimately maintaining the pressure at a desired level, i.e., corresponding to a constant reactive force exerted by the hydraulic fluid on piston **16**. Conversely, if the pressure in chamber **60** commences to drop, valve member **65** shifts to the right when viewing FIG. **3** under the influence of coil spring **75**, thereby reducing the orifice size of orifice **76**. This reduction in fluid pressure in chamber **60** thereby effectively provides a constant force exerted by the hydraulic fluid in chamber **36** against piston **16**.

A small amount of the incoming energy is stored in accumulator **40**. At the end of the stroke of piston **16**, valve **44** closes because the fluid pressures in chambers **60** and **64** are equalized due to the fact that no further positive displacement of piston **16** occurs. The fluid under pressure in accumulator **40** representing the stored energy thereof then flows in bypassing relationship to valve **44** through line **48**, control valve device **50**, valve **52**, line **54** and back to fluid flow passage **38** into chamber **36**. This increases the pressure of chamber **36**, causing piston **16** to move to the right when viewing FIG. **1** and causing it to be reset to its initial starting position. Thus, apparatus **10** is then ready to absorb the energy of another moving mass striking pad **24**.

Apparatus **10** operates to provide a substantially constant resistance to reactive force to a moving mass in engagement with pad **24** regardless of the velocity of the mass and irrespective of the position of piston **16** along its stroke. Valve **44**, defining a relief valve, provides the major portion of the aforesaid resistance. While the resistance provided by a relief valve is relatively constant compared to a spring or an orifice, it is not completely insensitive to velocity changes. This velocity variation can be kept small, however, by proper choice of valve **44**. A pilot operated relief valve is the preferred type and may have as little as **5** percent varia-

tion in resistance pressure between minimum and maximum velocity. However, the system of apparatus **10** compensates for such variations.

The resistance of buffer **12** is comprised of the pressure drop of valve **44,** pressure drop in fluid flow lines **42** and **46,** and the fluid pressure developed in accumulator **40.** As the buffer is actuated by the load, energy is dissipated and velocity decreases. Resistance of valve **44** drops slightly as the velocity decreases, the pressure drop in connecting pipes and lines also reduces as the velocity decreases. Accumulator pressure increases during this time and adds to the resistance. Proper selection of accumulator size and by providing a gas precharge therefor will result in a buildup of accumulator pressure so as to maintain a substantially constant total resistance pressure.

Apparatus **10** is essentially an energy dissipating system with only a small portion of the energy being stored. Precharging of the accumulator to slightly more gas pressure than required to overcome buffer restoration assures that there will always be enough pressure available to reset the buffer. The accumulator size is selected such that, as hydraulic fluid is forced into it, the pressure increase equals the decrease in the valve and line resistance due to velocity decrease.

The operating characteristic of apparatus **10** is shown in FIG. **2,** wherein the force exerted on piston **16** by the fluid in chamber **36** is represented by being constant afer a predetermined plateau has been reached. This plateau, represented by curve **90,** is reached when the fluid pressure in chamber **36** and thereby lines **42** and **46** and chamber **60** builds up sufficiently to cause pilot relief valve **66** to open. Thus, any further pressure increase will cause the main valve member **65** to open. Thereafter, variations in the fluid pressure due to velocity or displacement changes of piston **16** are compensated for by further opening or closing of valve member **65** relative to orifice **76.** Thus, the system characteristic of FIG. **2** represents the way in which apparatus **10** operates regardless of velocity or displacement changes of piston **16.**

I claim:

1. Energy absorbing apparatus comprising: a fluid buffer having a first, fixed, hollow part adapted to contain a hydraulic fluid and a second part mounted on the fixed part for movement relative thereto, said second part adapted to be engaged by a moving mass and to be shifted thereby relative to said first part in one direction to exert a force on the fluid therein; a fluid accumulator exterior of the buffer; means forming a first fluid flow path between said first part and said accumulator; means in said first path for defining a resistance to the increase of pressure in said first path after the pressure therein due to the force exerted by said second part on said fluid has reached a predetermined value; and means in bypassing relationship to said defining means for presenting a second fluid flow path to allow fluid directed to the accumulator along said first path to return to said first part, to thereby urge the second part in the opposite direction when the effect of the movement of said moving mass has been removed therefrom.

2. Apparatus as set forth in claim **1,** wherein said defining means includes a relief valve adapted to be opened and to maintain the fluid pressure in said first part at said predetermined value for substantially all values of velocity and operative positions of said second part relative to said first part.

3. Apparatus as set forth in claim **2,** wherein said valve is of the pilot-actuated type.

4. Apparatus as set forth in claim **1,** wherein said buffer comprises a fluid piston and cylinder assembly.

5. Apparatus as set forth in claim **1,** wherein said presenting means includes a fluid flow line having a check valve therein which permits fluid to flow only from the accumulator to said first part.

6. Apparatus as set forth in claim **1,** wherein the accumulator is precharged with a fluid.

7. Apparatus as set forth in claim **1,** wherein the said forming means, said defining means and the accumulator are separate from said buffer.

8. Apparatus as set forth in claim **1,** wherein is included a second buffer having a first, fixed, hollow part adapted to contain a hydraulic fluid and a second part disposed in and movable relative to the first part to exert a force on the fluid therein, said first part of the second buffer being in fluid communication with said forming means.

9. Apparatus as set forth in claim **1,** wherein said defining means includes a valve having a main valve portion and a pilot relief valve portion, said main valve portion being opened by fluid pressure in said first path only after said pilot relief valve portion has been opened.

10. Apparatus for absorbing the kinetic energy of a moving mass comprising: a fluid piston and cylinder assembly having means thereon for mounting the same in a support, the piston of the assembly being shiftable longitudinally of the cylinder thereof and having a shaft extending through the cylinder and projecting outwardly therefrom, the outer end of the shaft having a pad adapted to be engaged by a moving mass, the cylinder having a chamber remote from said shaft and containing a hydraulic fluid, there being a fluid passage through the cylinder in fluid communication with said chamber thereof, said piston being operable to pressurize the fluid in said chamber when a moving mass engages and moves said pad and thereby said piston in one direction; a fluid accumulator exteriorly of the assembly and adapted to be pressurized by fluid received thereby, whereby the accumulator can store energy in the form of fluid pressure; means defining a first fluid path between said fluid flow passage of the cylinder and the accumulator; a pilot-actuated relief valve disposed across said first path and being normally closed when the piston is in an initial operative position within the cylinder, said relief valve being opened when the fluid pressure in said first path has attained a predetermined value, said valve having means for maintaining the fluid pressure in said first path substantially constant for substantially all velocities and operative positions of the piston relative to the cylinder; a check valve; and means forming a second fluid flow path for coupling the check valve to the accumulator and to said fluid flow passage to permit return of fluid from the accumulator to said chamber after the piston movement in said one direction has been halted to thereby cause the piston to move in the opposite direction toward and into said initial operative position.

11. Apparatus as set forth in claim **10,** wherein the relief valve has a pilot relief valve portion and a main valve portion, the main valve portion being opened only after the pilot relief valve portion has been opened, and including means on the relief valve portion for biasing the same to a closed position, and means for adjusting the bias force of said bias means.

12. Apparatus as set forth in claim **10,** wherein is included a fluid flow control valve device coupled to said second path in series relatinship with the check valve.

* * * * *