June 19, 1956 P. H. TAYLOR 2,751,216

LIQUID SPRING

Filed Sept. 4, 1953

2 Sheets-Sheet 1

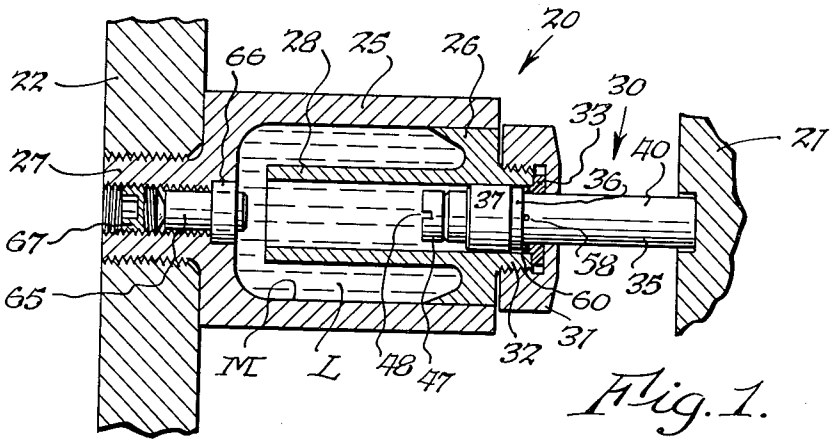


Fig. 1.

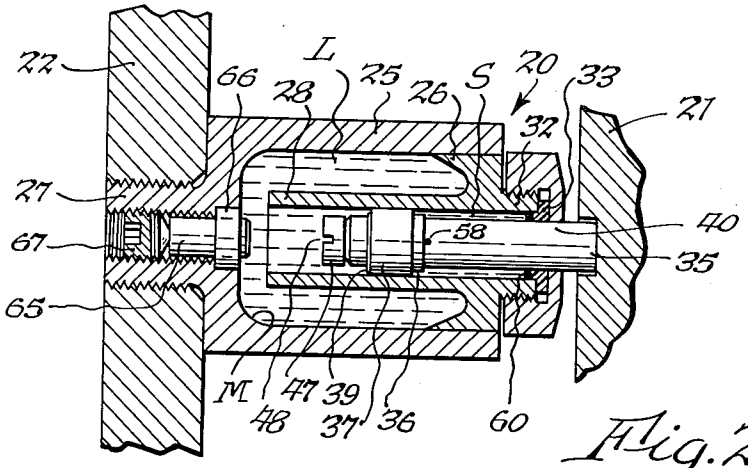


Fig. 2.

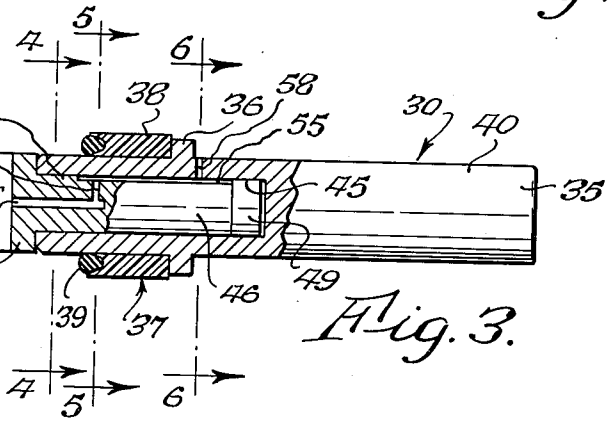


Fig. 3.

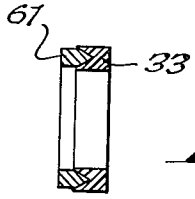


Fig. 9.

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LIQUID SPRING

Filed Sept. 4, 1953 2 Sheets-Sheet 2

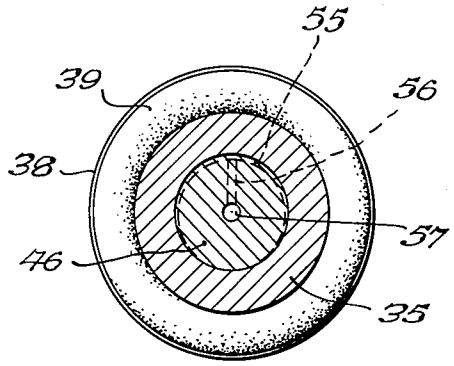


Fig. 4.

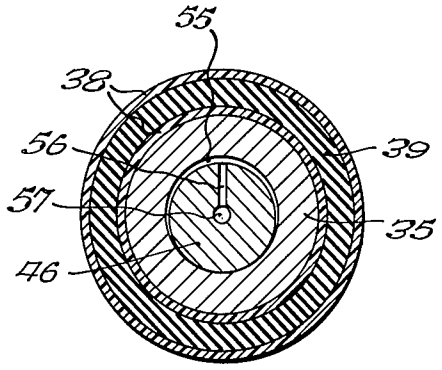


Fig. 5.

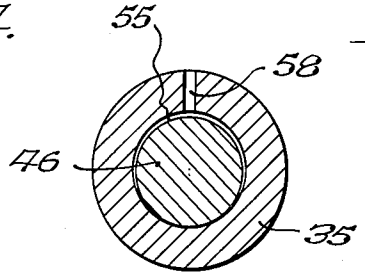


Fig. 6.

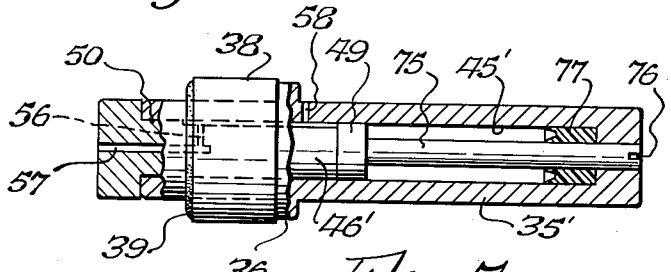


Fig. 7.

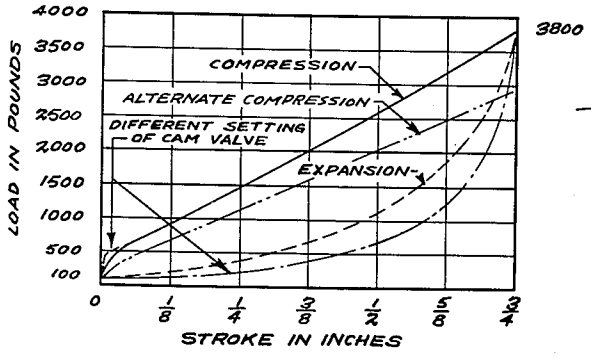


Fig. 8.

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2,751,216

LIQUID SPRING

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Application September 4, 1953, Serial No. 378,575

10 Claims. (Cl. 267—1)

The present invention relates to liquid springs, that is, to devices in which the compressibility of a confined liquid is utilized to effect resilient action and to cushion the movement of one part toward another under working load or force so that upon release of the working load or force the movable part will be restored to its initial position.

There are many requirements in the machine tool and other industries for a resilient cushioning device which is capable of providing resistance to movement in one direction but in which the energy stored up during such movement is decreased or dissipated on the return stroke of the device so that the return stroke may take place under substantially less force or less velocity than the working stroke. Obviously conventional mechanical springs are unsuited for this purpose for the energy which they store up, when being compressed, is almost exactly the same as the force they exert as they expand after the force of compression is released. This is true of all mechanical springs and is one reason why in many instances mechanical springs cannot be used satisfactorily.

Where one way operation with reduced force has been desirable, it has heretofore been the practice to employ air or liquid operating against air, the air being compressed upon the cushioning stroke and being valved on the return stroke so as to relieve the pressure to the extent and with the rapidity desired. One such application of this type is in the air cushion of a metal-working press where metal drawing is accomplished. In this type of apparatus a one-way operation is obtained by the valving action which eliminates the resilient force upon completion of the compression stroke. This makes certain that upon the withdrawal of the pressure of the press ram on the work-piece, the pressure of the air cushion does not cause a reversal of the metal draw in the workpiece and does not cause the workpiece to be restored to its original shape by virtue of continuance of the resisting spring pressure. Many like uses for springs, which have a high cushioning spring force but a return pressure that drops off rapidly, abound in various mechanical fields, but these possible uses are particularly prevalent in the field of metal-working. One specific application is to the cushion pad employed in drawing operations in the metal-working or drawing of metal objects. It is to this field that the present invention has particular application.

In many press operations it has heretofore been virtually impossible to obtain sufficient pressure to accomplish the desired operation in a single stage with the air cushioning means heretofore available. In fact, the lack of sufficient pressure within an air or mechanical cushioning device of a given volume is one of the reasons why several stage dies and a complex series of operations are often used.

To obtain greater pressure in a cushioning device of a given volume the liquid springs of the pending Taylor application Serial No. 180,966, filed August 23, 1950, and of the Zumwalt application Serial No. 228,215, filed March 12, 1952, and of the Wales application Serial No. 228,245, filed May 25, 1951, now Patents Nos. 2,708,109, 2,711,313 and 2,729,440 respectively granted May 10, 1955, June 21, 1955, and January 3, 1956, respectively, were devised. These devices enable attainment of extremely high pressures in a cushioning device of relatively small volume. However, these liquid springs, as heretofore constructed, are primarily a substitute for the mechanical springs used previously in metal-working operations. In other words, their main advantage lies in the fact that they are capable of developing pressures of six to ten times greater than conventional steel springs for a given volume. Through this ability alone, they are better for die operations than mechanical springs because they permit elimination of the extra stages of drawing required where conventional mechanical springs are normally used. However, where it is necessary for the cushioning medium to provide a high spring cushioning force in one direction that will drop off rapidly in the other direction, then liquid springs as previously constructed are unsuitable. It has still continued to be necessary to use pressure pads in presses for drawing operations, for instance. This, of course, has meant that such metal-working operations have had to be restricted to those presses in a factory or shop which are equipped with pressure pads and which have the pressure pad tonnage adapted to the work.

Many factories find it is impossible to schedule their work so as to have a continuous steady volume of drawing operations and another steady volume of punching or blanking operations. It is either a feast or famine, that is, many types of metal working operations require draw and pressure pad operations and some require none at all, with the net result that all the presses in a factory must be equipped with pressure pads in order to handle the feast of drawing operations, whereas none need be so equipped if the factory were doing all perforating or blanking. This then presents a serious problem, in that high expenditures for capital equipment must be made in the average metal working shop to be assured that the shop will at all times have sufficient presses equipped with pressure pads to enable it to do the complicated drawing operations which may be part of its work. Obviously a press equipped with a pressure pad having pressure pins extending through holes in its bed is a more expensive proposition than a simple stamping press having no pressure pad incorporated therein.

But aside from the disadvantage of having capital tied up in press equipment that is really merely for "stand-by" usage, dies with pressure pads require the piping of air, the use of accumulators and other kindred devices, which in themselves are often troublesome and the cause of greatly increased costs.

Another disadvantage of dies with pressure pads is the necessity for excessive press "down-time," because the dies must be mounted over the pressure pins which must then be connected to the portion of the die on which the pressure is to be exerted to effect the satisfactory operation of the draw. This "down-time" is a serious problem because it means that an expensive piece of machinery may be tied up as long as three or four hours while the die setup is being made in a given press.

Obviously much of the loss of time could be eliminated if it were possible to have a self-contained die apparatus in which the pressure pad means is incorporated into the die itself so that a drawing die could be installed or removed from the press as a unit rather than requiring costly and intricate setup attachment to the press. Obviously, also, the liquid springs in press working machines and the like could be greatly expanded if they were capable of one way operation, for then the need for pressure pads would be eliminated.

The primary object of the present invention is to pro-

vide an improved type of spring capable of providing a high spring force in one direction and a lesser force on its return stroke.

Another object of the invention is to provide a spring of the character described which is self-contained.

A further object of the invention is to provide a spring of the character described which can be varied as to preload, stroke load, and rate of drop-off of the force of its return stroke.

A further object of this invention is to provide a spring of the character described in which the load characteristics are variable according to the conditions which are required.

Another object of this invention is to provide a spring of the character described which is so constructed that the force of its return stroke can be varied after the spring is installed in a die and while the die is working within the press.

A further object of this invention is to provide a compact spring of the character described which may easily be installed in a die to make the die a self-contained and a working assembly which is not dependent for operation upon attachment to external sources of power.

Another object of this invention is to provide a spring of the character described which is adjustable as to the loads which it may carry.

Another object of this invention is to provide a spring which may be adjusted either to have its return force less than its cushioning force or to have its force of expansion equal to its cushioning force.

Another object of the invention is to provide a liquid spring which has the above enumerated features.

Still another object of this invention is to provide a replaceable element which may be incorporated in a standard liquid spring such as is disclosed in the Wales et al. copending application 180,966 above mentioned to provide a spring having less return force than its cushioning power.

Other objects of this invention will be apparent hereinafter from the disclosure and from the recital of the appended claims.

In the drawings:

Fig. 1 is a longitudinal section of a spring constructed according to one embodiment of this invention and shown attached between the pressure pad and the base of a die;

Fig. 2 is a similar section but showing the spring compressed;

Fig. 3 is a view with parts broken away of the piston assembly of this novel spring;

Fig. 4 is a transverse section taken on the line 4—4 of Fig. 3 looking in the direction of the arrows;

Fig. 5 is a transverse section taken along the line 5—5

Fig. 6 is a similar section but taken along the line 6—6 of Fig. 3 looking in the direction of the arrows;

Fig. 7 is a part elevation, part section of a modified piston assembly;

Fig. 8 is a graph showing typical compression and expansion strokes of a spring built according to this invention, and showing the difference in movement obtainable therewith by adjustment of the spring; and

Fig. 9 is an axial section of a pressure ring that may be used with the seal of a spring built according to this invention.

In Fig. 1 there is shown a liquid spring **20** of the general configuration of that disclosed in my copending application Serial No. 228,245 above mentioned. This spring is shown contained between the base **21** of a die set and a pressure pad **22** of the die set. The spring comprises a chamber or container **25** which is closed at one end by a head **26** that is welded or otherwise secured to it against leakage, and which has a projecting portion **27** at its other end that is externally threaded to thread into the pressure pad **22**. The head **26** is formed with

a central tubular portion **28** that extends internally into the chamber **25** and that forms a cylinder in which the piston assembly **30** reciprocates. A nut **31** threads on the outwardly extending neck portion **32** of head **26** to retain the piston assembly **30** in the chamber; and secured between the nut **31** and the neck portion **32** is a seal **33**.

The piston assembly comprises a piston **35** having a shoulder **36** and carrying a seal **37**. The shoulder **36** and seal **37** together constitute the head of the piston. The seal **37** shown is of the type more particularly described in the copending application of Charles Lee Rovoldt Serial No. 298,094, filed July 10, 1952, now Patent No. 2,708,573, granted May 17, 1955, assigned to the assignee of the present application. It comprises a nylon or other resilient plastic sleeve **38**, which has a circular V-shaped notch in it at its inner end, and a rubber O-ring **39** which is mounted in this notch. Sleeve **38** is of a dimension to fit tightly in the bore of cylinder **28** and may even be made a few ten-thousandths of an inch oversize so that it has to be compressed to insert it in this bore. The sleeve **38** is of larger diameter than the shank portion **40** of the piston so that space S will be provided in the cylinder **28** around the shank **40** as the piston moves inwardly.

Mounted in a counterbore **45** in the inner end of the piston **30** is a rotatably adjustable plug **46**. This plug has an enlarged head **47** at its rear which seats against the rear face of the piston **35**. The plug has a transverse kerf **48** in its rear face which is adapted to receive a screwdriver by which the plug may be rotated.

The plug has bearing portions **49** and **50** adjacent opposite ends which serve to support it rotatably in the counterbore **45** of the piston and which are coaxial of the axis of rotation of the plug and counterbore. Between the bearing portions **49** and **50**, however, the peripheral surface of the plug is shaped so that it is eccentric of the plug axis.

The eccentric portion of the plug is adapted to fit tightly at one side against the counterbore, but between the counterbore and the rest of the periphery of the eccentric portion of the plug there is a gap **55** as clearly shown in Figs. 3, 5 and 6. The plug has a radial duct **56** which leads from the space or gap **55** to an axial duct **57** that terminates in kerf **48**. A small hole or orifice **58** is drilled radially in the piston outwardly of its shoulder **36**. This hole extends into the portion of the counterbore **45** into which the eccentric portion of the plug **46** extends. When the gap **55** between the eccentric portion of the plug and the counterbore is in registry with hole **58**, then, the compressible liquid L, with which the container is filled, can flow from one side of the piston head to the other through ducts **57** and **56**, gap **55** and hole **58**. By adjusting the plug rotatably the rate of flow of the liquid from one side of the piston to the other can be controlled; and if the plug is rotated to a position diametrically opposite that shown in Figs. 3, 5 and 6, the flow can be shut off entirely. The spring will in this latter case act then as a conventional liquid spring, the energy, which is stored up on the compression or working stroke of the spring, exerting its full force to return the piston when the compression force is released.

The seal **33** for preventing leakage of the compressible liquid from the container along piston **35** is made of nylon or a similar material and has a circular V-shaped groove **60** in its inner face like the V-groove in seal **38**. In some instances it may be desirable to employ with this seal a pressure ring **61** (Fig. 9) so that the bearing loads transmitted to the seal through the shoulder **36** of the piston will be carried through the seal **33** without damaging its sealing lips. This is essential where high preloads are desired on the spring, but may be dispensed with where the loads are insufficient to cause the lips of the seal to be crushed.

Referring now to Figs. 1 and 2 it will be seen that as

the piston 35 is forced inwardly into the cylinder 28 the liquid L in the container 25 will be compressed and some of this liquid will be forced through kerf 48, ducts 57 and 56, gap 55 and hole 58 into the space S on the outer side of the piston. The rate at which the liquid will flow will depend, of course, upon the rotary position of the plug 46. This can be varied but in most instances because of the rapidity of operation of the spring the plug is adjusted to give a full load from the spring as indicated by the compression line in Fig. 8. However, by varying the gap 55 the load can be varied. Thus, by increasing the gap an alternate compression curve of action will be obtained such as shown in Fig. 8. It will be noted that the liquid in space S is in a compressed condition. Thus, there is compressed liquid between the shoulder 36 and seal 33, a condition not found in conventional liquid springs.

When the ram of the press is reversed at the end of its working stroke the working force is relieved from the piston 35. Then the energy stored up in the compressible liquid in the main portion M of the chamber expands, acting on the seal 38, to force the piston outwardly on its return stroke. The liquid in the space S on the outer side of the seal exerts a resisting pressure causing the effective pressure on the inner side of the seal 38 to be diminished in direct proportion to the pressure exerted against the outer face of the seal. This is because of the difference in diameter between the seal 38 and the portion of seal 33 which engages piston 35. Since the full force of the compressed liquid is acting on the inner face of seal 37, however, the liquid in front of seal 37 bypasses back through orifice 58, gap 55, ducts 56 and 57 and kerf 48 to the main chamber M of the container. Thus, the return stroke of the piston is slowed down and an expansion load or curve is produced such as shown in Fig. 8. By adjusting plug 46 rotatably the gap or passage 55 can be closed off to any desired extent, and, in fact, can be shut off entirely if desired. An expansion curve corresponding to a different setting of the cam valve or plug 46 is also shown in Fig. 8. When the gap or passage 55 is shut off entirely, the spring, as previously stated acts like a conventional liquid spring, its expansion load being as great as its compression load.

A force adjustment means is preferably provided in the spring simlar to that disclosed in copending application Serial No. 228,245 above mentioned. This force adjustment means comprises a plunger 65 mounted to be slidably adjustable in a seal 66 in the portion 27 of the container. A screw 67 which threads into extension portion 27 serves to adjust plunger 65. Seal 66 may be similar in construction to seal 37. The force adjuster is for preloading the spring and for compensating for any liquid leakage from the spring.

An alternative construction of piston is shown in Fig. 7. Here the structure is generally the same as in Fig. 3 except that the plug 46' has no kerf in its inner end but has a rod-like forwardly projecting extension 75 which extends through the outer end of piston 35'. This extension 75 has a kerf 76 in its outer end which may be engaged by a screwdriver or the like to rotatably adjust the plug. Piston 35' may be of the same construction as piston 35 except that its counterbore 45' is somewhat longer so as to accommodate rodlike extension 75 and a seal 77 for preventing leakage along the extension 75. Parts in Fig. 7, which are identical with parts in Fig. 3, are designated by the same reference numerals as in Fig. 3.

While the invention has been described in connection with different embodiments thereof, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains, and as may be applied to the essential features hereinbefore set forth and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. A liquid spring comprising a closed container filled with a compressible liquid, a cylinder fixed to one end of said container and mounted to extend inwardly into said container and opening thereinto at its inner end, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends outwardly of said container through the outer end of said cylinder, said cylinder being closed at its outer end except for the opening through which the piston shank passes, and means for passing liquid from said container into the space between the piston head and the outer end of said cylinder on the inward stroke of said piston.

2. A liquid spring comprising a closed container filled with a compressible liquid, a cylinder fixed to one end of said container and mounted to extend inwardly into said container and opening thereinto at its inner end, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends outwardly of said container through the outer end of said cylinder, said cylinder being closed at its outer end, except for the opening through which the piston shank passes, and a duct for passage of liquid from said container into the space between said piston head and the outer end of said cylinder.

3. A liquid spring comprising a closed container filled with a compressible liquid, a cylinder fixed to one end of said container and mounted to extend inwardly into said container and opening thereinto at its inner end, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends outwardly of said container through the outer end of said cylinder, said cylinder being closed at its outer end, except for the opening through which the piston shank passes, and said piston having a duct therethrough for passage of liquid from said container into the space between said piston head and the outer end of said cylinder.

4. A liquid spring comprising a closed container filled with a compressible liquid, a cylinder fixed to one end of said container and mounted to extend inwardly into said container and opening thereinto at its inner end, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends outwardly of said container through the outer end of said cylinder, said cylinder being closed at its outer end, except for the opening through which the piston shank passes, and said piston having a duct therethrough for passage of liquid from said container into the space between said piston head and the outer end of said cylinder, and adjustable means for varying the size of the opening of said duct.

5. A liquid spring comprising a closed container filled with a compressible liquid, a cylinder fixed to one end of said container and mounted to extend inwardly into said container and communicating therewith, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends outwardly of said container through one end of said cylinder, said cylinder being closed at said one end except for the opening through which said piston shank passes, and a duct connecting the space between said piston head and said one end of said cylinder with said container.

6. A liquid spring comprising a container filled with a compressible liquid, a cylinder mounted to extend into said container and opening thereinto at its inner end, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends through the outer end of said cylinder, said cylinder being closed at its outer

end except for the opening through which said piston shank passes, said piston being counterbored at its inner end, a plug rotatably mounted in said counterbore, said plug having a portion only of its periphery eccentric of its axis of rotation, said eccentric portion providing a gap between said plug and said counterbore, said plug having a duct leading from the inner end of said piston to its eccentric peripheral portion and said piston having a duct communicating with said eccentric peripheral portion and leading into the space between said piston head and the outer end of said cylinder.

7. A liquid spring comprising a closed container filled with a compressible liquid, a cylinder fixed to one end of said container and mounted to extend inwardly into said container and opening thereinto at its inner end, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends outwardly of said container through one end of said cylinder, said cylinder being closed at said one end except for the opening through which said piston shank passes, a duct connecting the inner end of said piston with the space in said cylinder between said head and said one end of said cylinder, and a member rotatable in said piston to control the flow of liquid between said container and said space through said duct.

8. A liquid spring comprising a container filled with a compressible liquid, a cylinder fixed to one end of said container and mounted to extend inwardly into said container and opening thereinto at its inner end, a piston reciprocable in said cylinder and having an enlarged head slidable in said cylinder and a shank of reduced diameter which extends outwardly of said container through the outer end of said cylinder, said cylinder being closed at its outer end except for the opening through which said shank passes, said head being counterbored at its inner end, a plug rotatably mounted in said counterbore coaxial therewith, said plug having bearing portions adjacent its ends which have diameters substantially equal to the diameter of said counterbore, said plug having a portion only of its periphery between said bearing portions eccentric to its axis of rotation, said eccentric portion providing a gap between said plug and said counterbore, said plug having a duct leading from the inner end of said head to the outside of its eccentric peripheral portion, and said piston having a duct extending from the outside of its shank to said counterbore.

9. A piston for use in a liquid spring, said piston having an enlarged head which has a counterbore in one end,

a shank of reduced diameter connected with the opposite end of said head, a plug rotatably mounted in said counterbore coaxial therewith, said plug having bearing portions adjacent its ends which have diameters substantially equal to the diameters of said counterbore and having a portion only of its periphery between said bearing portions eccentric to its axis of rotation, said eccentric portion providing a gap between said plug and said counterbore, a duct leading through said plug from said one end of said head to the outside of its eccentric peripheral portion, and a duct in said shank which communicates at one end with said counterbore and at its other end with the outside of said shank at the side of said head remote from said one end of said head, the first-named duct, said gap, and the second-named duct forming a passage from one side of said enlarged head to the other when said plug is rotatably adjusted so that the eccentric portion of its periphery is in register with said second-named duct.

10. A piston for use in a liquid spring, said piston having an enlarged head, a shank of reduced diameter as compared with said head, a counterbore in one end, a plug rotatably mounted in said counterbore and adjustable about the axis of said counterbore, said plug having a portion of its periphery between its ends which is eccentric of said axis, said eccentric portion providing a gap between said plug and said counterbore, a duct leading through said plug from said one end of said piston to said eccentric portion of the periphery of said plug, and a duct leading to said eccentric portion of the periphery of said plug from the periphery of said piston at the side of said head remote from said one end of the piston.

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