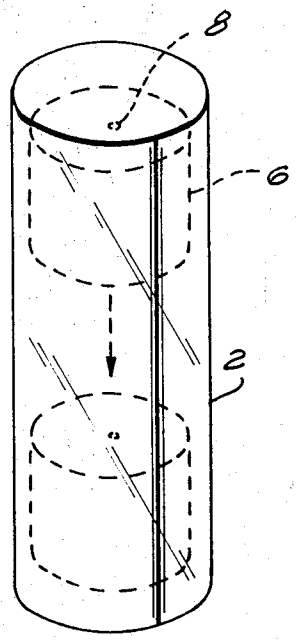
Feb. 16, 1971 D. S. BREED 3,563,024

SHARP EDGE ORIFICE DASHPOT TIMER

Filed Aug. 27, 1969 2 Sheets-Sheet 1

FIG. 1



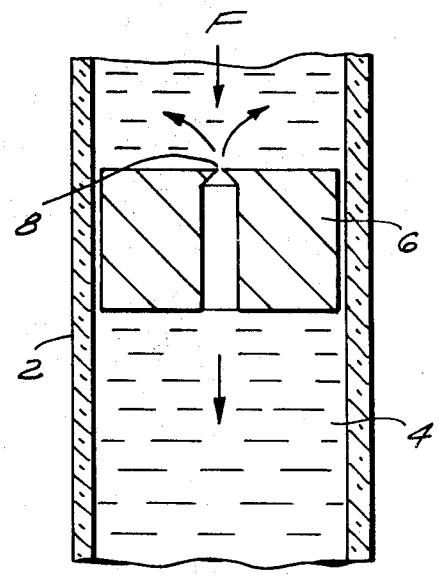


FIG. 2

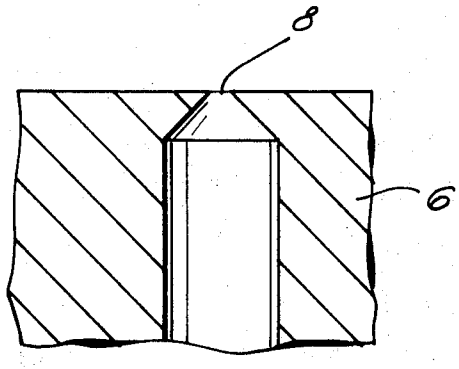


FIG. 3

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Feb. 16, 1971 D. S. BREED 3,563,024

SHARP EDGE ORIFICE DASHPOT TIMER

Filed Aug. 27, 1969 2 Sheets-Sheet 2

FIG. 4

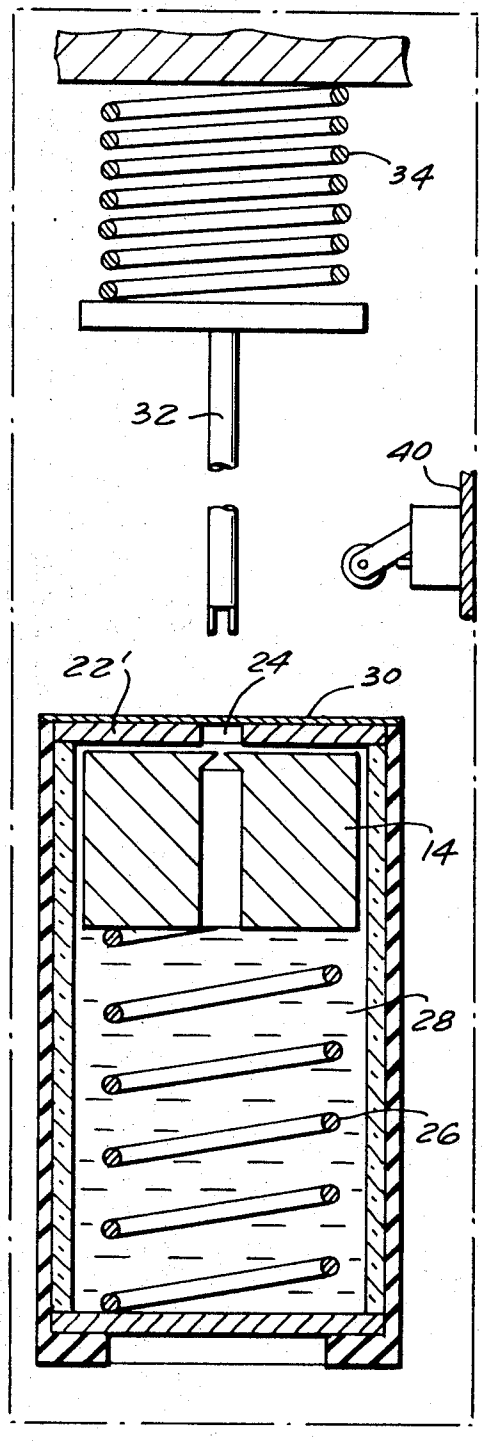
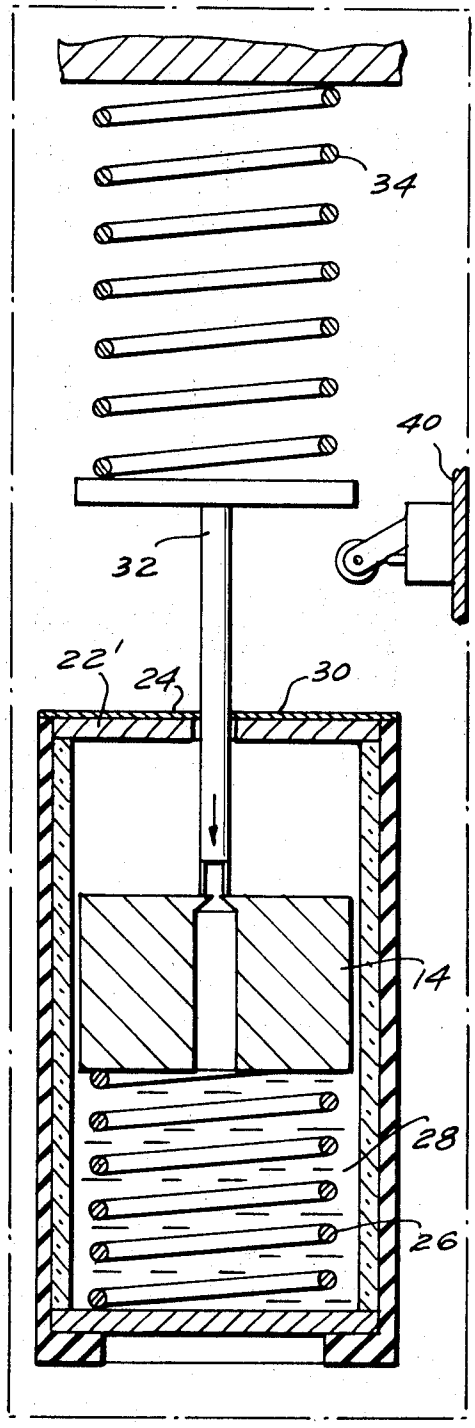


FIG. 5



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3,563,024

SHARP EDGE ORIFICE DASHPOT TIMER

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Filed Aug. 27, 1969, Ser. No. 853,473
Int. Cl. G04b 45/00
U.S. Cl. 58—2 8 Claims

ABSTRACT OF THE DISCLOSURE

The dashpot timer of this invention includes a substantially cylindrical glass tube in which travels a piston having a diameter slightly less than that of the interior of the tube. A low viscosity liquid defines the medium in the cylinder in which the piston containing a sharp edge orifice is adapted to travel. The flow ingenerated in the cylinder is predominantly an inertial flow through the sharp edge orifice with the shear flow and pressure flow between the piston and cylinder being relatively insignificant. The device of the present invention operates in the inertial flow region whereby the viscosity effects are relatively small compared with the inertial effects of the fluid.

The subject invention relates to a liquid sharp edge orifice dashpot which utilizes the clearance between an axisymmetric piston and an interior cylindrical wall as the seal between the piston moving relatively to the cylinder and containing a sharp edge orifice through which the liquid is metered.

Dashpots utilizing air as the metering fluid are known in the art and are described in Pat. No. 3,171,245. Such air dashpots are finding wide acceptance for certain time delays having certain functions of the applied force or where the available force is within certain narrow limits. Applications requiring relatively large force variations ranging from a few ounces to many pounds or where it is desired to have the time delay vary with the inverse square root of the applied force, or both, timers heretofore unavailable and unrealized are necessary. For such cases the liquid sharp edge orifice dashpot timer of this invention has been found to be eminently satisfactory and acceptable and capable of yielding time delays ranging from a few milliseconds to several hours and more.

The usual dashpot timers of the above patent also tend to be somewhat larger than the available space can accommodate. As the desired time delay increases, the size of such timers increase and the available space becomes increasingly inadequate. The dashpot timer of this invention is capable of being reduced to minute sizes while providing the aforenoted long delays. A typical timer contemplated is less than ¾ inch long and ½ inch in diameter.

The liquid sharp edge orifice dashpot is also desirable in that it is relatively insensitive to changes in ambient pressure and temperature.

An understanding of the particular nature of the flow past a piston as it descends along the wall of a cylinder and through a sharp edge orifice in the piston is important in determining the predictability and accuracy of the rate of descent. The type of liquid flow that the present invention utilizes is generally termed inertial flow through the orifice and creeping and shear or pressure flow between the piston and cylinder which involves very slow liquid motion between the piston and cylinder, that is, motion at very low Reynolds numbers and in which viscous forces are predominant over inertial forces whereas the opposite is the case for the flow through the sharp edge orifice in the piston where the liquid velocity is large yielding large Reynolds numbers and thus the inertial forces predominate over the viscous forces. The

size of the orifice and piston-cylinder clearance is such that the dominant portion of the flow occurs through the sharp edge orifice with the small clearance between the piston and cylinder thus acting as a seal.

It is, therefore, an object of the present invention to provide a liquid sharp edge orifice dashpot which eliminates the disadvantages, limitations and drawbacks of the prior art devices and which is exceptionally reliable, susceptible to long life and relatively inexpensive to manufacture.

The liquid dashpot of the subject invention has been successfully utilized as a constant distance arming delay system for artillery. In this application, the dashpot piston is acted upon by centrifugal force due to the spinning shell and the piston mass. Since this force varies with the square of the spining velocity and since the flow through the sharp edge orifice as the square root of the applied force, the flow varies as the first power of the spin. Furthermore, since for most shells the ratio of spin to forward velocity is approximately constant, the piston velocity is proportioned to the shell velocity regardless of the actual velocity of the shell. For a fixed travel of the piston, therefore, constant distance arming is achieved for artillery independent of the particular muzzle velocity. Although several approaches may be taken to seal the liquid in the cylinder, the present invention proposes to seal the liquid through the use of a thin metal membrane which is punctured by a rod sufficiently small in diameter to puncture the membrane at the initiation of the delay. Thus, the dashpot of the subject invention can be stored for long periods of time without the danger of liquid loss.

Other objects and advantages will become apparent from the following detailed description which is to be taken in conjunction with the accompanying drawings illustrating an exemplary preferred embodiment of the invention and in which:

FIG. 1 is a diagrammatic perspective view of a dashpot timer incorporating the teachings of this invention utilizing a piston containing the sharp edge orifice the initial and terminal position of which for the prescribed time delay being shown in dotted lines;

FIG. 2 is an enlarged fragmentary longitudinal sectional view of this dashpot showing the internally disposed piston traveling through the selected liquid to an applied force;

FIG. 3 is an enlarged fragmentary sectional view of the piston showing the sharp edge orifice in detail;

FIG. 4 is a longitudinal sectional view illustrating the dashpot employed in an exemplary embodiment employing a puncturing pin prior to the initiation of the time delay sequence; and

FIG. 5 is a view similar to FIG. 4 but showing the device after the delay sequence has been initiated.

Referring now to FIGS. 1 and 2, a dashpot timer of this invention will include an outer cylinder **2** having a contained liquid **4** therein through which a piston is adapted to travel under an applied force F. The piston also defines with the inner surface of the cylinder's relatively small annular clearance through which a small portion of the liquid passes. The major portion of the fluid passes through the sharp edge orifice **8**.

In order to seal the liquid **28** in the cylinder, a thin metal membrane **30** is designed to overlie the upper plate **22'**.

A plunger **32** is mounted externally of the cylinder in alignment with the aperture **24** of the plate **22'**. The plunger is designed to travel along its axis, and in the illustrated embodiment is powered by a spring **34**.

Upon initiation of the timing sequence, a suitable mechanism (not illustrated) releases the plunger whereby

it penetrates the membrane **30** and enters the cylinder through the aperture **24**. The plunger **32** then strikes the piston **14** which is retained adjacent the aperture **24** by the spring **26**. By design, the force exerted by the spring **34** is somewhat larger than that exerted by the spring **26** such that the piston descends along the cylinder at a controlled rate. Thus, the distance which the plunger **32** has traveled along its axis provides a convenient measure of elapsed time and varies as the square root of the applied force. Through the use of conventional mechanisms, the plunger can be utilized to trigger various devices, such as an arming mechanism **40** of an artillery shell.

The motion of the piston in the cylinder depends on the equation of inertial fluid flow through a sharp edge orifice providing the flow in the clearance between the piston and cylinder can be neglected. This relationship is:

$$Q=K\sqrt{\frac{2\Delta P}{\delta}}A$$

where:

Q=volume flow rate in.^{3}/sec.
K=experimental constant (usually about .7)
ΔP=pressure drop across the orifice
δ=density of fluid
A=area of the orifice

This equation holds for large Reynolds' numbers where the viscous effects can be neglected.

The time delay for a given piston travel can be found from the relationships

$$\frac{dx}{dt}=\frac{Q}{A'}$$

$$\Delta P=\frac{E}{A'}$$

solving

$$\frac{dx}{dt}=\frac{K}{A'}\sqrt{\frac{2F}{\delta A'}}A$$

or if the force is independent of time

$$t=\int_0^l \frac{dx}{\frac{KA}{A'}\sqrt{\frac{2F}{\delta A'}}}$$

where:

l=length of piston travel
t=time delay
f=applied force
A'=area of piston cross section

Since the viscosity does not appear in this equation, the time delay will be independent of the viscosity insofar as the assumptions made above hold. That is, the Reynolds' number must be much larger than 1, and the fluid flow between the piston and cylinder must be negligible. The first assumption requires the use of a low viscosity fluid if the device is to operate over a wide range of temperature (−65° F. to +160° F.) and force (5 to 30 lbs.). For a particular design a one centipoise silicone fluid has functional well over the above ranges of force and temperature.

For most devices contemplated, the radius would be less than about ½ inch. The pressure could vary from about 5 p.s.i. to several thousand p.s.i. The clearance would probably never exceed .001". The viscosity could vary from 1 centipoise to over 1000 centipoises. However, for most of the devices, the upper limit would probably be about 100 centipoises. For conversion purposes, centistokes × density=centipoises and 1,000,000 centipoises=.14 lb. sec./in.^{2}. Fluids of these or equivalent types are available commercially.

For most applications, however, no temperature compensation would be necessary. The viscosities of the

optimum fluids change by a factor of 35 to 1 over a temperature range of −65° F. to +160° F. This fact above all others has prevented the use of liquid dashpots per se as timing elements in military fuses in the past.

The cylinder **12** is preferably made from glass or other ceramic material, since precision glass tubes are readily available. However, other materials could also be utilized. Similarly, the end plates **22** and **22'** could be made from glass or a metal such as aluminum. The plates may be integrally formed with the cylinder or may be bonded to the ends of the cylinder.

In summary, the present invention accomplishes and contributes the following advantages to the dashpot timer art:

(1) Time delay as function of the square root of the applied force: For all other fluid dashpots, the time delay will follow some other function of applied force. To achieve constant distance arming for artillery shells, the time delay must vary as the inverse square root of the applied force. This is accomplished through the inertial flow equation for a sharp edge orifice.

(2) Temperature compensation: The viscosity of the best fluids change by a factor of 35 to 1 over the temperature range −65° F. to +160° F. Even over a very limited temperature range, the viscosity changes about 1%/° F. to 1.5%/° F. Consequently, if accuracy is to be achieved even over limited temperature ranges the Reynolds ° number for the flow through the sharp edge orifice must be large compared to 1.

(3) Piston rates: For most of the devices of the present invention, the rate of travelof the piston will be on the order of 300 micro-inch per sec. to 50 inches per second. The most important range effectively satisfied by this invention is the .1 to 25 inches per sec. area.

(4) Sealing: The second major reason why liquid dashpots have failed in military applications has been the inability to seal silicone fluids from leakage. With the use of a metal membrane punctured by a rod at the initiation of the delay, there is no sealing problem.

(5) Military applications: Based on present knowledge, no intertial flow liquid dashpot has been successfully applied to a military fuse in the past. Other applications and other than one-time use dashpot timer applications may be found in the above-identified patent.

(6) Piston cylinder seal: Based on present knowledge, no liquid dashpots have been made wherein the clearance between the piston and cylinder is the seal. Where orifice-type dashpots have been utilized in the past in a piston-cylinder configuration, "O" rings or similar type seals have been used.

Although a preferred embodiment of this invention has been described and illustrated herein, it should be understood that this invention is in no sense limited thereby but its scope is to be determined by that of the appended claims.

I claim:

1. A liquid, sharp edge orifice dashpot timer comprising:

a cylinder having a substantially cylindrical interior wall;

a piston disposed in said cylinder and having an outer diameter slightly less than the diameter of said interior wall and containing a sharp edge orifice whereby the major portion of dashpot liquid flow occurs through the sharp edge orifice;

a liquid of relatively small viscosity in the cylinder through which the piston is adapted to move with the relative flow of the liquid being inertial flow through the orifice and flow in lubrication region between the piston and cylinder, which involves Reynolds' numbers much larger than 1 in the orifice so that the viscous effects can be neglected for flow through the orifice and the inertial forces dominates.

2. The invention in accordance with claim **1** wherein the piston is substantially cylindrical and the piston rate of

travel through the liquid being defined by the following equation:

$$\frac{dx}{dt}=\frac{KA}{A'}\sqrt{\frac{2F}{\delta A}}$$

when the flow in the clearance is neglected, where K is an experimental constant, F is the axial force applied to the piston, δ is the density of the liquid, A is the area of the orifice, A' is the piston cross section area, and dX/dT is the velocity of the piston.

3. The invention in accordance with claim 2 wherein the radius of the piston is less than about ½ inch.

4. The invention in accordance with claim 2 wherein F/A' is of a value of about 5 p.s.i. to several thousand p.s.i.

5. The invention in accordance with claim 2 wherein h, the piston-cylinder clearance, is less than .001 inch.

6. The invention in accordance with claim 2 wherein δ is of a value from .65 centistoke to 1000 centistokes.

7. The invention in accordance with claim 6 wherein the liquid is selected from the group of silicone fluids ranging in viscosity from .65 centistoke to 1000 centistokes.

8. The invention in accordance with claim 7 wherein the viscosity of the liquid changes by a factor of 35 to 1 over the temperature range of −65° F. to +160° F., and the device operates with a Reynolds' number substantially greater than 1 over this temperature range.

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RICHARD B. WILKINSON, Primary Examiner

E. C. SIMMONS, Assistant Examiner

U.S. Cl. X.R.

58—144; 267—1; 188—87