Nov. 6, 1951 J. E. PRACHE 2,574,059

HYDROPNEUMATIC RECUPERATOR FOR GUNS

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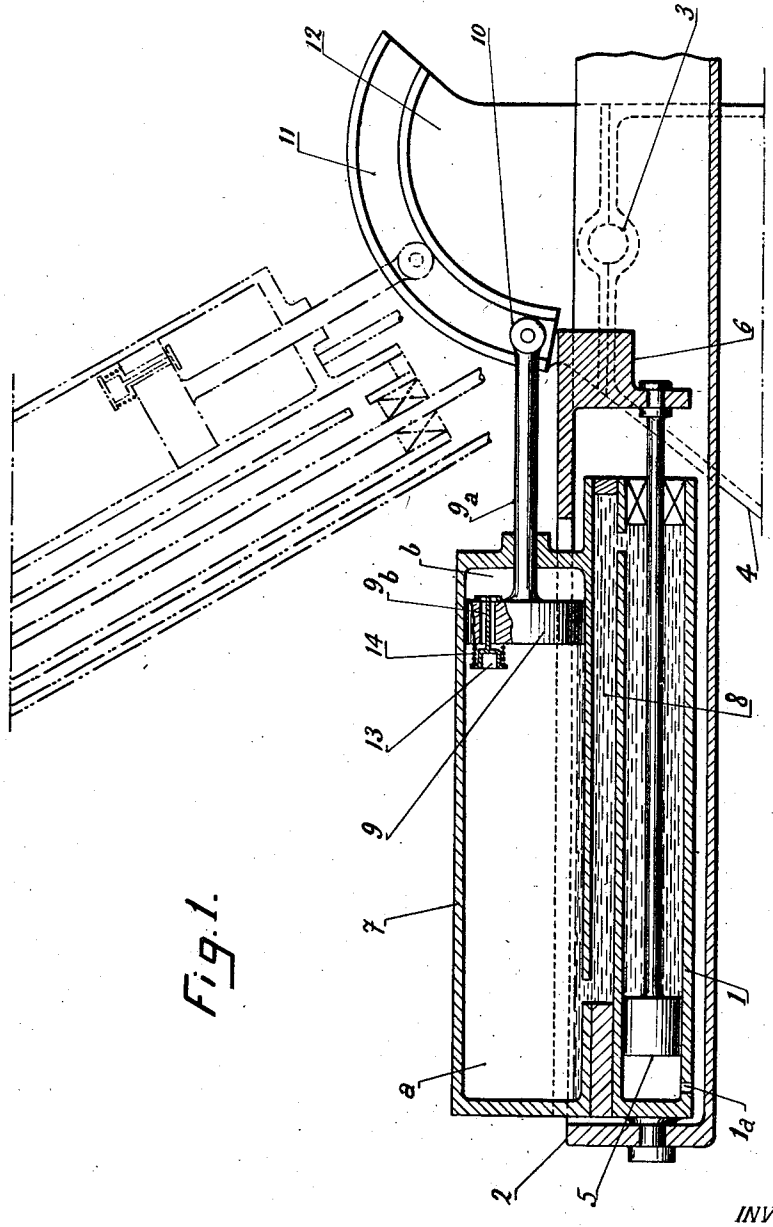


Fig. 1.

INVENTOR

Jacques Emilien Prache

BY Cameron, Kerkam, & Sutton

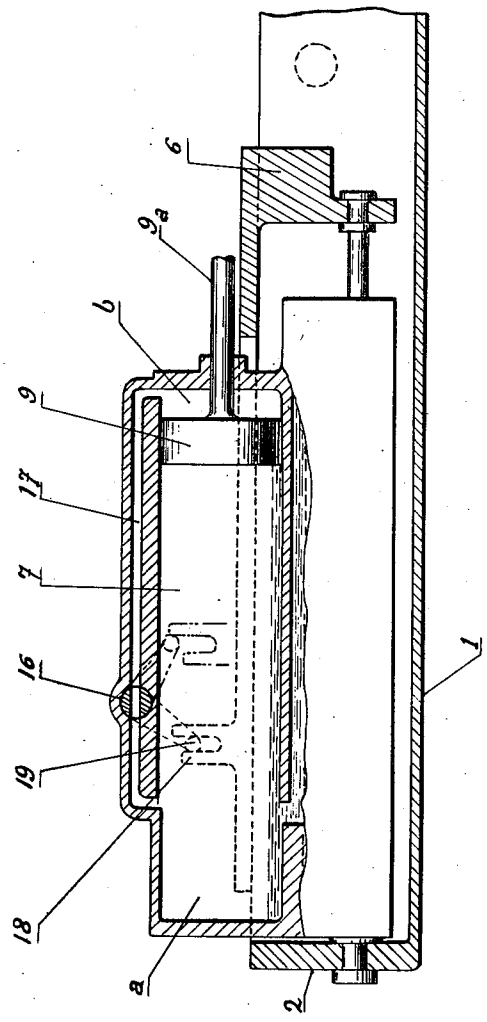
ATTORNEYS

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HYDROPNEUMATIC RECUPERATOR FOR GUNS

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Fig. 2.



INVENTOR

Jacques Emilien Prache

BY Cameron, Kerkam, & Sutton

ATTORNEYS

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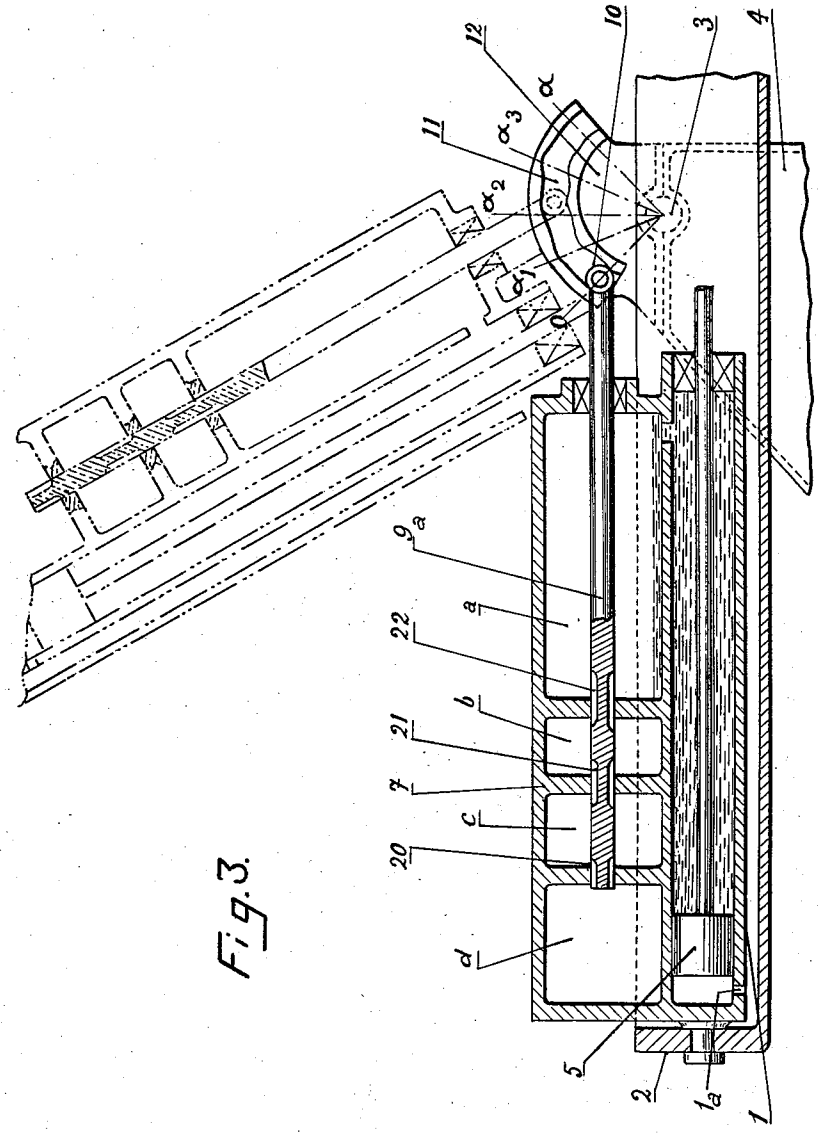


Fig. 3.

INVENTOR

Jacques Emilien Prache

BY Cameron, Kerkam, & Sutton

ATTORNEYS

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HYDROPNEUMATIC RECUPERATOR FOR GUNS

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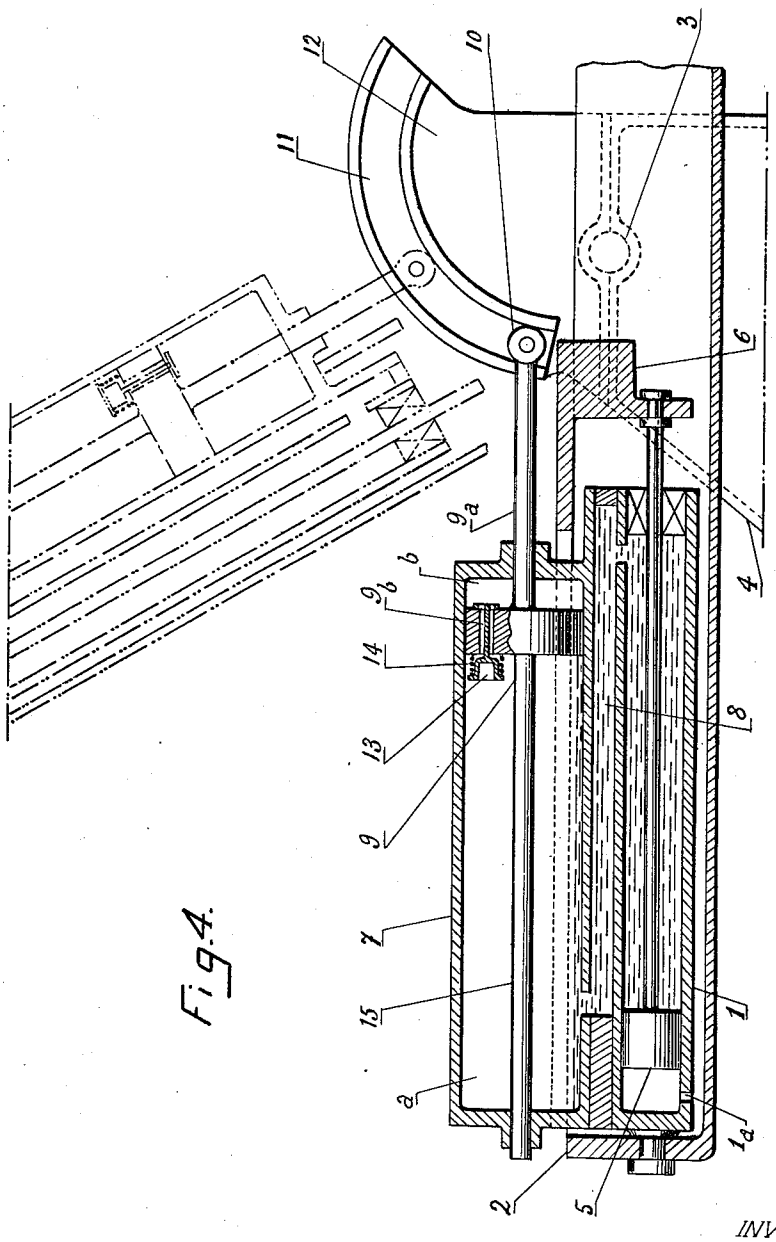


Fig. 4.

INVENTOR

Jacques Emilien Prache

BY Cameron, Kerkam, & Sutton

ATTORNEYS

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UNITED STATES PATENT OFFICE

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HYDROPNEUMATIC RECUPERATOR FOR GUNS

Jacques Emilien Prache, Fontenay-sous-Bois, France, assignor to Schneider & Cie, Paris, France, a joint-stock company of France

Application April 25, 1947, Serial No. 743,998
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10 Claims. (Cl. 89—43)

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This invention concerns hydro-pneumatic or pneumatic recuperators, which are more particularly intended for pieces of artillery having a large vertical field of fire, and has for its object to provide means which permit inter alia of automatically regulating, as a function of the angle of fire, the power of braking and of returning into battery position possessed by these recuperators without modifying their initial latent energy.

It has already been proposed to vary the power of such recuperators as a function of the laying angle by acting on the initial pressure of the compressed air contained in the air reservoir, this being effected by delivering into the said reservoir, by means connected with the elevating mechanism, variable quantities of the liquid contained in the hydraulic cylinder associated with the said reservoir so as to reduce the volume occupied by said air.

However, it will readily be understood that at increasing laying angles the control of the operation of delivering liquid into a reservoir containing air under high pressure by the elevating operation superposes a considerable additional load on the normal elevating force whereas, on the contrary, with decreasing laying angles, the expansion of the aforesaid air is capable of imparting a dangerous acceleration to the oscillating mass.

These disadvantages are radically eliminated by the present invention, owing to the fact that the desired variation of power is only prepared during the laying in elevation and only becomes effective upon firing, this double result being obtained, according to the essential feature of the said invention, by regulating the initial volume of air subjected to compression at the recoil (which may be designated as the "useful air") as a function of the laying angle, but without changing its pressure. In other words, it is not then the initial latent energy of the recuperator which is rendered dependent upon the laying in elevation since this remains constant at all angles, but its potential energy, that is to say, that which it will store up at the recoil. It will hereinafter be seen that the variation of volume in question may be obtained with a minimum expenditure of force.

It can moreover readily be shown that this mere variation of the initial volume of the gas as a function of the laying angle permits of inversely varying the energy accumulated by the recuperator for a given recoil.

If, in fact, the initial volume of the air is designated by V_0, its final volume after a given recoil L by V_f, and the ratio

$$\frac{V_o}{V_f}$$

by K, while its initial thrust is designated by F_0, it is known that the energy stored up T_r is expressed by:

$$T_r = F_o L \frac{K}{K-1} \log_e K \qquad (1)$$

which shows that T_r varies proportionately to

$$\frac{K}{K-1} \log_e K$$

the value of this product increasing when K increases, as can readily be verified.

Now, the volume V_0 being established for the minimum angle, if for a given laying angle α a certain volume v is cut off therefrom, the initial volume at this angle becomes $V_0 - v$ and the final volume $V_f - v$ (since the recoil stroke does not change). The ratio of the initial volume to the final volume therefore becomes:

$$K_1 = \frac{V_o - v}{V_f - v}$$

which value is greater than that of

$$\frac{V_o}{V_f}$$

that is to say of K.

Since the value of K has increased with the increased gun elevation or laying angle, it is deduced therefrom with reference to the Equation 1 that the value of T_r has itself increased.

In practice, the variation of the initial volume reserved for the useful air may be continuous as a function of the laying angle, or may be effected step by step, which is sufficient in practically all cases.

An example of the embodiment of each of these two conceptions is illustrated in the accompanying drawings, as applied to a recuperator of the type constituted by a cylinder filled with liquid, which cylinder is independent of the brake cylinder and in which there moves a piston which, at the recoil, delivers the said liquid into a compressed-air reservoir.

Figure 1 is a diagrammatic sectional elevation of a hydro-pneumatic recuperator in which the initial volume occupied by the useful compressed air varies continuously as a function of the laying angle.

Figure 2 shows a variation of the same arrangement.

Figure 3 is a similar section of a recuperator in which the initial volume of useful compressed air varies discontinuously.

Figure 4 is a diagrammatic sectional elevation of a modification of the recuperator shown in Figure 1.

In the form of embodiment illustrated in Figure 1, the recuperator is constituted by a cylinder 1 coupled with a cradle 2 which oscillates during vertical laying about horizontal trunnions 3 supported by the carriage 4. In this cylinder moves a piston 5 coupled with the recoiling part 6, the said piston delivering the liquid at the recoil from the cylinder into a compressed-air reservoir 7 connected to the cylinder 1 and communicating freely therewith through a channel 8. As shown, the channel 8 and the portion of cylinder 1 lying to the rear (to the right as viewed in the drawing) of piston 5 are completely filled with liquid, while the portion of cylinder 1 in front of piston 5 is vented to the atmosphere through an orifice 1_a.

According to the invention, the cylindrical capacity of the air reservoir 7 is divided into two compartments *a* and *b* by a piston 9, the rod 9_a of which extends in an air-tight manner through the rear end of the air reservoir and supports at its extremity a roller 10 arranged so as to traverse a guide groove 11 during laying in elevation, the said groove being connected to the carriage and suitably profiled. The separating piston 9 is provided with a conduit 9_b in which there is fitted a check valve 13 maintained in the unseated position when the gun is in battery by a spring 14 of weak tension, thus permitting communication between the two compartments *a* and *b*.

When the cradle 2, under the action of the elevating mechanism, is subjected to a positive angular displacement about the trunnions 3, the roller 10, rolling in the groove 11, causes the piston 9 to slide towards the front of the reservoir 7. The chambers *a* and *b* remain in communication with one another during the entire displacement, the spring 14 being so calibrated as to maintain the valve 13 in the open position even when the angular laying velocity is at a maximum. There is an exchange of gas between *a* and *b* without any variation of pressure, the total volume remaining constant except for the negligible variation due to the penetration of the rod 9_a of small diameter. The chamber *a* which, as will hereinafter be seen, is intended to confine the initial useful volume V_o of gas, consequently changes in volume as a function of the inclination, according to the law imposed by the profile of the guide groove 11.

The barrel being laid at any angle, when the firing takes place, the recoiling mass 6 carries along the recuperator piston 5 which delivers a certain quantity of liquid from the cylinder 1 into the compartment *a*. The pressure in this compartment suddenly rises and causes the valve 13 to close immediately, the result of which is to place the chamber *b* out of circuit, i. e., out of communication with the chamber *a*. The compression of the recuperator and consequently the energy stored up during the recoil therefore depend solely upon the volume of the chamber *a* at the laying angle in question, and it has hereinbefore been seen that this energy varies inversely with the variation of the initial volume of the said capacity.

During return into battery position, the liquid is delivered into the cylinder 1 by the expansion of the gas confined in the chamber *a*, the pressure

of which, while decreasing progressively, nevertheless remains greater than that existing in *b* until the return into battery position is completed. The valve 13 therefore remains closed until the return into the initial position. At this moment, the pressures in *a* and *b* balance one another and the valve opens, re-establishing the communication between the two compartments.

It will readily be seen that during the laying operation the displacement of the piston 9 only requires the small effort necessary for overcoming the passive resistances and the initial pressure of the gas acting on the single cross section of the rod 9_a of the said piston. This latter part of the effort may even be eliminated by the addition of a compensating rod 15 of equal diameter to the rod 9_a, on the opposite face of the piston, as indicated in Figure 4.

As will be seen from the variation illustrated in Figure 2, the communication between the compartments *a* and *b* may be effected through a conduit 17 in the wall of the air reservoir 7, the piston 9 then being solid.

In order to avoid irregular closure of the said valve under the influence of an increase in pressure due to a more rapid temperature increase in *a* than in *b*, a cock 16 is disposed in the conduit 17 connecting the two compartments *a* and *b* regardless of the position of the piston 9.

This cock 16 will be controlled positively, for example by a dog 18 having two unequal branches, which is secured to the recoiling mass 6 and acts on crank 19 of the said cock.

In the battery position, the cock is maintained open and, as soon as the recoil commences, it is closed by the forward or shorter branch of the dog 18 which, after the closing, leaves the crank. Upon return into battery position, it is the rear branch, that is to say the longer, which acts on the crank 19 and reopens the cock.

It is obvious that any other automatic valve, cock device or slide valve having a positive control may be adopted.

In the embodiment illustrated in Figure 3, the mass oscillating during the laying in elevation is constituted by the same elements, designated by the same reference numerals, as those shown in the preceding figures, but in this case the reservoir 7 is subdivided permanently by fixed partitions into a number of compartments *a*, *b*, *c*, *d*. The aforesaid separating piston 9 is then replaced by a multiple slide valve designed to establish or interrupt communication between the various aforesaid compartments. This slide valve is constituted by a rod 20 sliding in a fluid-tight manner in orifices located in alignment in the partitions and in the rear end of the reservoir 7. This rod is controlled by the angular displacement of the oscillating mass through its roller 10, which is made to traverse the fixed cam groove 11. The cams correspond to predetermined laying angles $\alpha 1$, $\alpha 2$, $\alpha 3$, and are separated by sections concentric to the trunnions 3. Channels 20, 21, 22 are provided in the rod 9_a at the points at which it passes through the various partitions, so as to ensure the inter-communication of all the compartments during the laying of amplitude $\alpha 1$. Their lengths are such that the successive increasing displacements of the rod 9_a by the cam groove 11 ensure the placing out of circuit, first of all of the compartment *d* and then of the following compartment *c* and finally of the third compartment *b*, so as to pass in stages from the complete chamber $a+b+c+d$ for the minimum laying angle to the single compartment *a* for the

maximum angle and vice versa. To each of these stages corresponds a graduated power of the recuperator.

Naturally, the control of the slide valve 3a could be obtained by other means than a cam connected to the carriage, and could also be rendered dependent, not upon the laying of the barrel with respect to the carriage, but upon the angle of fire in the particular case where the platform on which the carriage is mounted is itself adapted to undergo considerable deflections from the level position, which is the case in particular with armoured vehicles. It is, in fact, obvious that the regulation of the initial volume of the useful air would then have to be a function of the true inclination of the barrel with respect to the true horizontal or to the true vertical.

Finally, it must be understood that the invention covers any other arrangement of the component chambers enclosing the air under pressure in which means are provided for placing one or more of these chambers in or out of circuit, and that such means could, for example, be controlled by the laying of the barrel in elevation.

Regardless of the method of application adopted, it is to be observed that if it is assumed that the law of variation of the initial volume of the useful air is assumed to be established principally with the object of rendering the recoil uniform, there will be obtained as a secondary advantage a certain regulation of the duration of the return into battery position and vice versa.

In fact, as has been shown, the energy accumulated in the recuperator during the recoil is greater in proportion as the angle of laying is greater and that consequently during the return into battery position the resistant work of the force of gravity is greater. The energy available and the resistant work therefore vary in the same sense, which tends to render the return accelerations uniform.

Although the invention has hereinbefore been described exclusively in its application to a recuperator of variable power intended to co-operate in the braking of the recoil and to ensure the return of the recoiling mass of pieces of artillery into battery position, it will be clear to any person skilled in the art that it is also applicable to accumulators of hydro-pneumatic or pneumatic energy employed for other purposes when it is necessary to vary their power. Thus, for example, again in the sphere of artillery, it may be applied directly to hydro-pneumatic or pneumatic rammers for the round, which are directly influenced by the laying movements of the barrel and placed under tension at the recoil.

I claim:

1. In a recoil system for a moving mass which is adapted to be moved to various angular positions relative to the horizontal, a cylinder, a piston in said cylinder, a piston rod secured to said piston and to the moving mass, a second cylinder in free communication with said first named cylinder, a piston in said second cylinder intermediate the ends thereof, a piston rod for said second piston, a conduit connecting the portions of said second cylinder lying on opposite sides of said second piston, a normally open valve in said conduit, means controlled by the moving mass for closing said valve during each recoil movement of said mass and means connected to said second piston rod for varying the position of said second piston according to the angle of elevation of the moving mass.

2. In a recoil system for a gun, a cylinder, a piston in said cylinder, a piston rod secured to said piston and to a recoiling portion of said gun, a second cylinder in free communication with said first cylinder, a piston in said second cylinder intermediate the ends thereof, a normally open passageway through said second piston connecting the portions of said second cylinder lying on opposite sides of said piston, means for automatically closing said passageway during each recoil movement of the gun and means for varying the position of said second piston according to the elevation of the gun.

3. In a recoil system for a gun, a cylinder, a piston in said cylinder, a piston rod secured to said piston and to a recoiling portion of said gun, a liquid in said cylinder, a second cylinder in free communication with said first cylinder, a gaseous medium in said second cylinder compressible by the liquid displaced from said first cylinder by the movement of said first piston during recoil and means for decreasing the effective volume of said second cylinder as the elevation of the gun is increased without change in the initial pressure of said gaseous medium.

4. A system as described in claim 3 in which said means includes a piston mounted in said second cylinder, a normally open port through said piston and valve means for closing said port during recoil of the gun.

5. A system as described in claim 3 in which said means includes a piston mounted in said second cylinder, a piston rod for said second piston, a cam secured to the gun carriage and engaging said second piston rod, a normally open port through said second piston and means for closing said port during recoil of the gun and maintaining said port closed until the gun returns to battery.

6. A system as described in claim 3 in which said means includes a piston mounted in said second cylinder, a normally open by-pass around said second piston, valve means in said by-pass and means for closing said valve means during recoil of the gun.

7. A system as described in claim 3 in which said means includes a piston mounted in said second cylinder, a piston rod for said second piston, a cam secured to the gun carriage and engaging said second piston rod, a normally open by-pass around said second piston, a valve in said by-pass and automatic means for closing said valve during recoil of the gun and for reopening said valve as the gun returns to battery.

8. A system as defined in claim 3 in which said means includes at least one partition in said second cylinder having a normally open port therein and valve means actuated by the elevation of the gun for closing said port.

9. A system as defined in claim 3 in which said means includes a plurality of axially spaced partitions in said second cylinder having ports therein, a valve rod sliding in said ports and a cam secured to the gun carriage and engaging said valve rod, said valve rod being so constructed and arranged that said ports will be open when the gun is not elevated and will be successively closed as the gun is elevated.

10. In an accumulator of hydro-pneumatic or pneumatic energy of the variable power type wherein the accumulation of energy results from recoil movement of a movable mass and the amount of energy accumulated varies with the position of said mass prior to recoil, a cylinder, a piston in said cylinder, a piston rod connecting

said piston to said mass so as to move said piston in the cylinder in accordance with the recoil movements of said mass, a second cylinder in free communication with said first cylinder, said second cylinder being partially filled with a compressible fluid medium, the remainder of said second cylinder and the portion of said first cylinder in free communication therewith containing a liquid, a piston in said second cylinder intermediate the ends thereof which is stationary during recoil and against which said fluid medium is compressed by the influx of liquid into said second cylinder from said first cylinder and means for varying the position of said second piston according to the position of said mass prior to recoil without simultaneously varying the pressure of said compressible fluid medium.

JACQUES EMILIEN PRACHE.

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