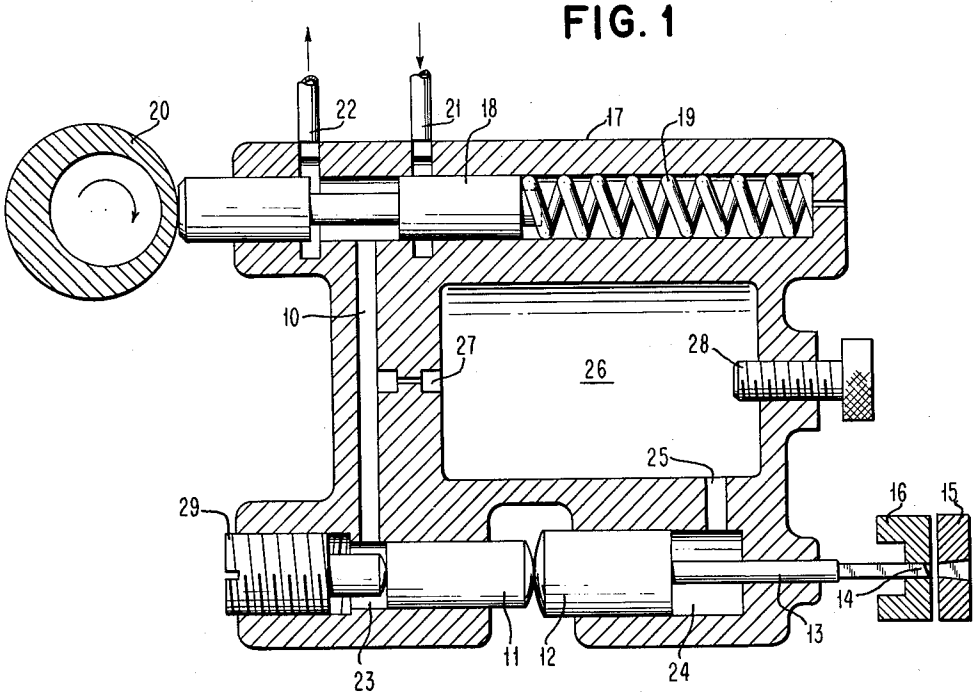
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FLUID APPARATUS

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FIG. 1



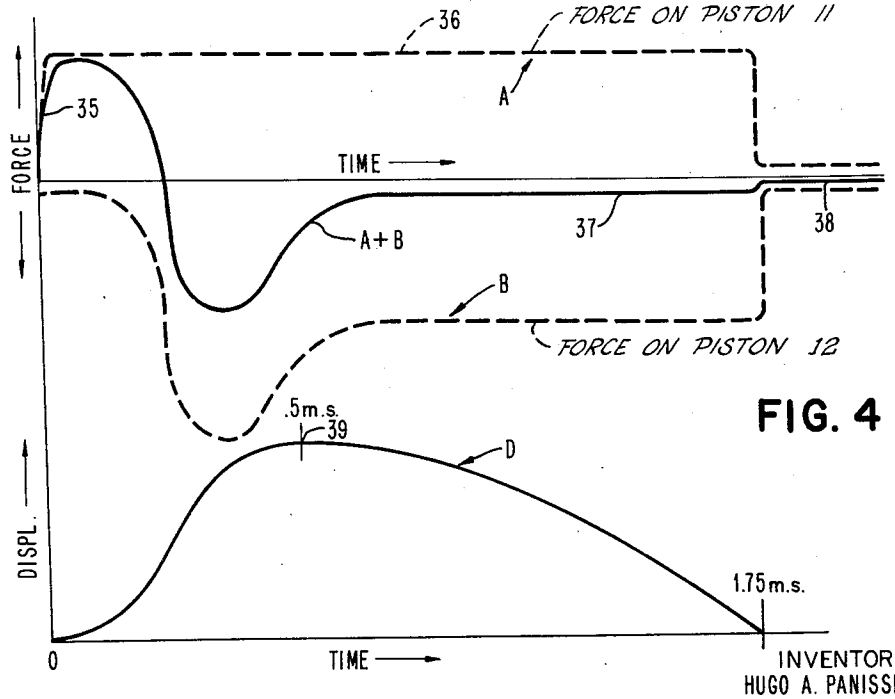
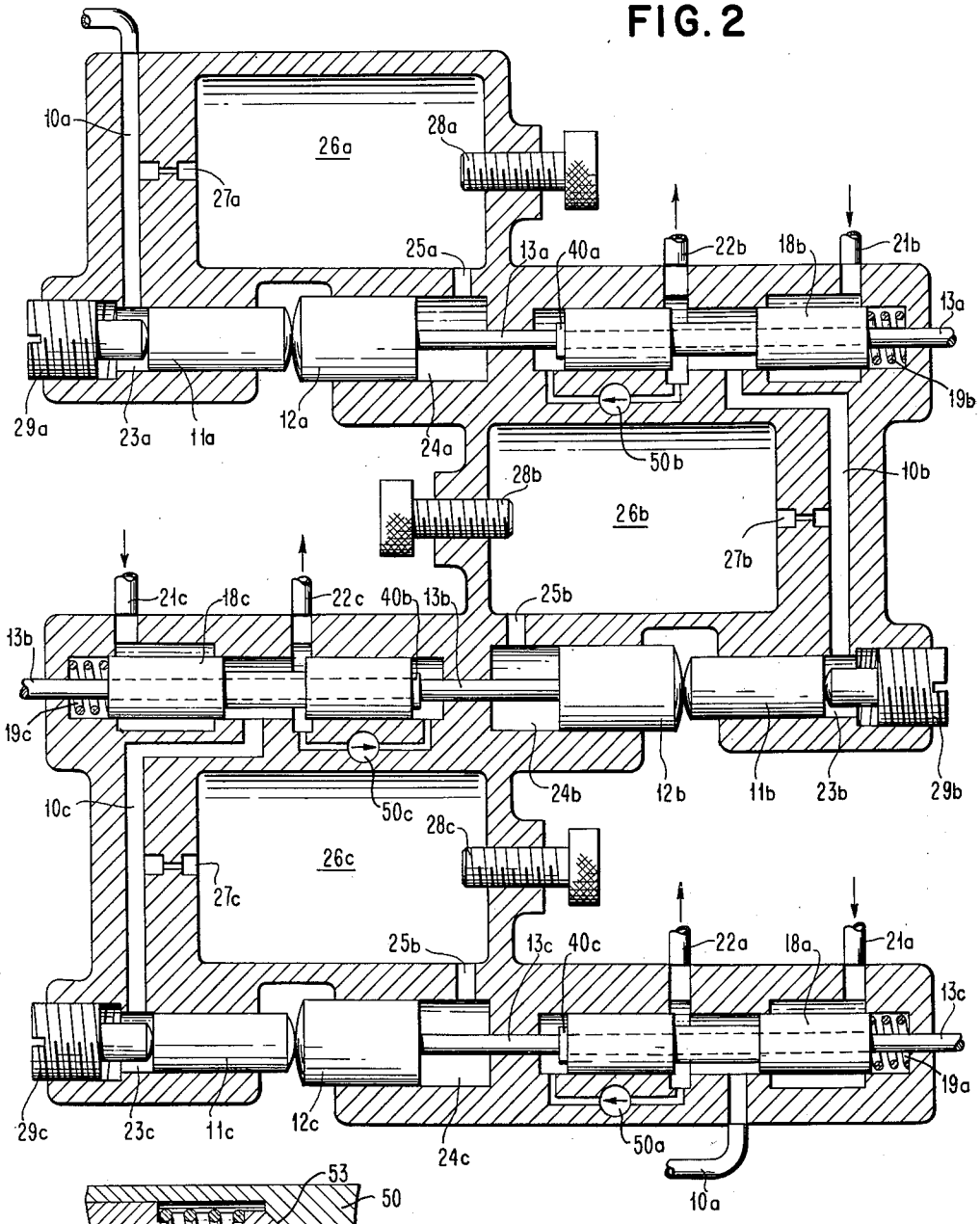




FIG. 4

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FIG. 2


10a
26a
28a
27a
25a
13a
40a
22b
18b
21b
13a
19b
29a
23a
11a
12a
24a
50b
28b
26b
10b
27b
21c
18c
22c
40b
13b
25b
13b
19c
10c
50c
24b
12b
11b
23b
29b
28c
26c
27c
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12c
24c
50a
10a

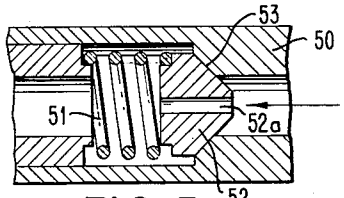

53
50
51
52a
52

FIG. 5

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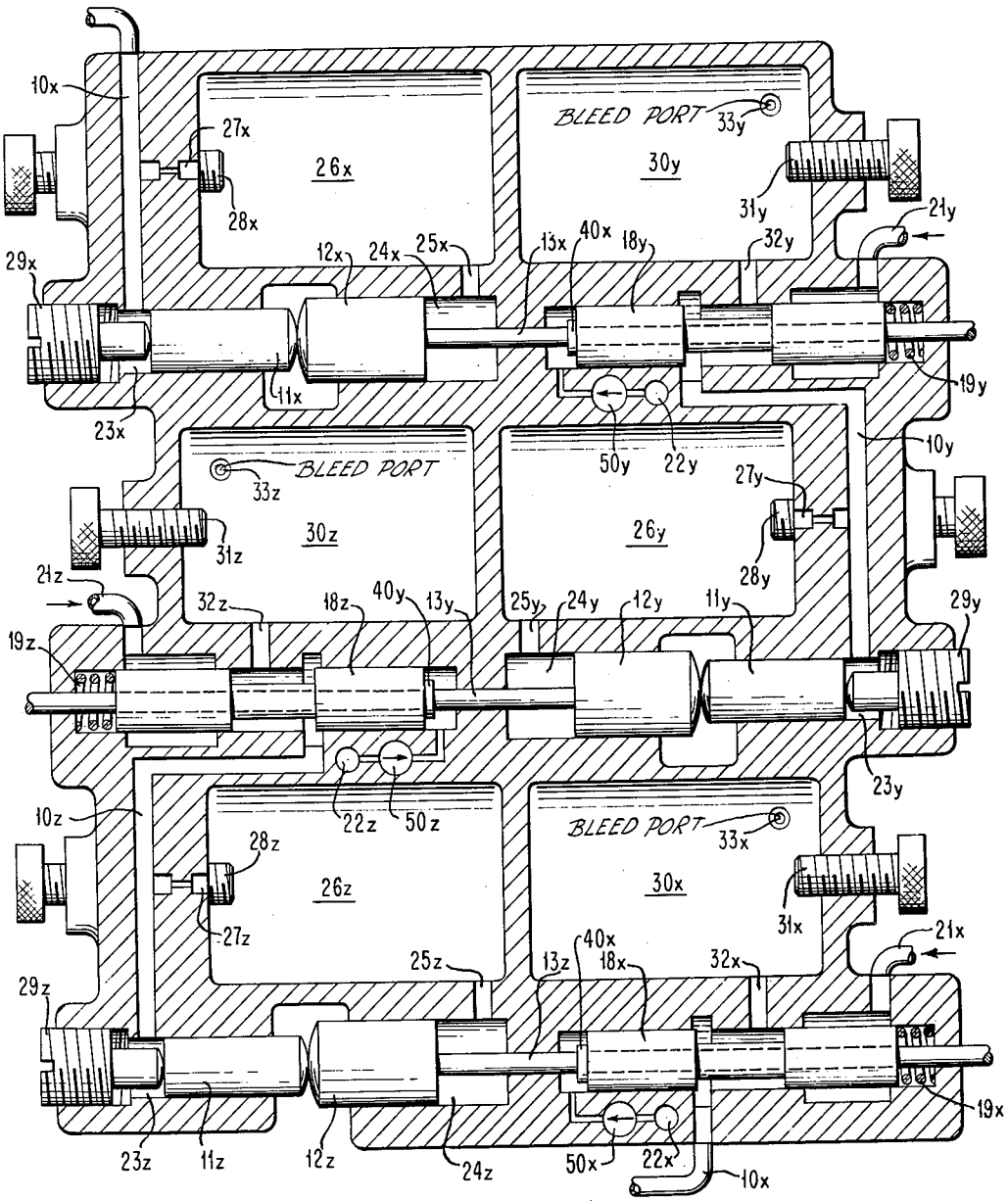



FIG. 3

United States Patent Office 3,058,310 Patented Oct. 16, 1962



3,058,310

# FLUID APPARATUS

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6 Claims. (Cl. 60—97)

This invention relates to fluid apparatus and more particularly to a fluid actuated prime mover for producing a very rapid reciprocating motion in response to a single applied pressure impulse, and to a cascaded arrangement of these basic operators whereby each operator controls the production of a pressure impulse for the actuation of the next succeeding operator in the chain.

Historically, fluid apparatus and particularly hydraulic apparatus has generally been employed for the production of slow speed movement with considerable force, and it has only been recently that fluid devices have been used in high speed applications. Particularly in the field of automatic data processing equipment and digitally controlled machine tools has hydraulics been increasingly utilized for the precise control of high speed equipment. Examples of the use of high speed hydraulics in the data processing equipment are to be found in magnetic tape feeds and paper feed carriages to name but a few. It is to the end of producing a basic fluid apparatus useful in applications such as these that the instant invention is principally directed. Inasmuch as the apparatus hereinafter to be described produces an extremely rapid reciprocatory movement, it is particularly adapted for functions such as document card punching or similar uses, although, it will be readily appreciated, that being a basic prime mover, it will find utility in any apparatus wherein such function is required.

Whereas in prior art devices sharp pressure surges resulting in "fluid hammer" have always been sought to be avoided as a deleterious phenomenon, the instant invention fully exploits such former disadvantage to produce a very rapid acting fluid operator which depends for its very speed on fluid pulses and more particularly on a fluid pulse delay. A further departure from prior art concepts and practice is the recognition and utilization of the compressibility of the fluid employed in the system, particularly the more viscous fluids such as hydraulic oils which have hitherto been thought of as incompressible, or at least such within the operating range of prior art systems. Thus, by a reversal of former design criteria the present invention incorporates these hitherto unappreciated and deleterious phenomena in a simple and economically fabricated fluid operator having a faster operating response than known devices.

It is therefore an object of this invention to provide a fluid apparatus operative responsive to a single applied fluid pressure impulse to produce an extremely rapid reciprocation of an output member.

A further object of the invention is to provide a fluid apparatus operative in response to a single applied fluid pressure impulse to apply the pressure impulse directly to one side of a motion producing member and to delay the application of the said impulse to the opposing side of said member whereby the member is reciprocated with extreme rapidity.

Yet another object of the invention is to provide a chain of fluid apparatuses in accordance with the foregoing objects wherein each individual apparatus provides the fluid pressure pulse for the actuation of the next succeeding apparatus in the chain.

A still further object of the invention is to provide a fluid apparatus operative responsive to a single applied fluid pressure impulse wherein the said impulse is applied directly to one side of a motion producing member to produce motion thereof in a first direction and also to a compliance chamber wherein the pressure impulse produces a compression of the fluid which fluid compression is expanded to the opposite side of said motion producing member to produce a return motion thereof after a slight delay, whereby said motion producing apparatus is reciprocated with extreme rapidity.



An even further object of the invention is to provide a fluid apparatus operative in response to a single applied fluid pressure impulse to produce a rapid single stroke reciprocating motion wherein the reciprocation is effected by a double-ended piston slideably contained in a cylinder having opposed pressure chambers in communication with the opposite ends of said piston, one of said chambers being directly connected to said source of fluid pressure impulse and the other being connected thereto via a compliance chamber and a flow restrictor whereby said pressure impulse is applied directly to one end of said piston and delayed in its transmission to the opposite end thereof so as to produce a rapid reciprocation of said piston by the successive reaction to the oppositely acting direct and delayed pressure impulses.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIGURE 1 is a sectional view of a single stage pulse responsive operator employed as a punch.

FIGURE 2 shows three stages of cascaded pulse operators.

FIGURE 3 shows a modification of FIGURE 2.

FIGURE 4 is a graphical representation of the force and displacement relationships with respect to time.

FIGURE 5 shows details of a valve used in FIGURES 2 and 3.

In FIGURE 1 the basic form of the apparatus is shown and, simply stated, functions when pressure is suddenly applied to the pipe 10 to move the pistons 11 and 12 rapidly to the right and then to the left. Such movement has been shown to be utilized by an external connection via piston rod 13 to a punch 14 operating in a die 15 and stripper 16 to punch any material introduced in the interspace between the die and stripper, or alternatively to produce useful work to any output mechanism requiring a short-stroke rapid reciprocating motion.

The foregoing summary of the function of the apparatus is achieved by providing a unitary housing 17 containing a spool valve 18, which valve is biased to the left in the figure by a spring 19, the valve bearing on its leftmost end upon a rotatable eccentric cam 20, the rotation of which will cause the spool valve 18 to translate in its bore in the housing 17 to alternately expose the duct 10 to source pressure in the duct 21 or sump pressure in the duct 22. Thus the spool valve 18 serves to produce in the duct 10 a pressure pulse. Equally well, the duct 10 could be connected to a piston in a closed system such that a mechanical shock could be externally introduced to produce the pressure pulse. The only requisite is that the pressure in the duct 10 be of a pulse nature as the apparatus is insensitive to steady state conditions. Connected directly to the duct 10 is the chamber 23, which chamber contains the piston 11, which piston abuts a larger piston 12, which seals and varies the volume of a further chamber 24, which chamber communicates with the duct 10 through duct 25, compliance chamber 26 and flow restrictor 27. With the above apparatus in the position shown in FIGURE 1, a 180° rotation of the eccentric 20 will move the valve 18 to the right sealing the duct 22 and opening the duct 21 to the duct 10. The

pressure impulse thus created and appearing in the duct **10** will react in the chamber **23** upon the piston **11** to move it, the abutting piston **12**, the connected piston rod **13**, and punch **14** to the right. During such movement fluid will be pumped out of the chamber **24** and into the compliance chamber **26**. At the same time the pressure pulse appearing in the duct **10** will be delayed in its transmission into the compliance chamber **26** by the flow restrictor **27**. The pressure in the compliance chamber **26** will, however, rise very rapidly and the fluid therein will be compressed to such a degree that the pressure in the compliance chamber **26** will be greater than the source pressure and the pressure in the chamber **24** will correspondingly rise. When such rise occurs the piston **12** will overcome the piston **11** and the apparatus will decelerate and return to the left to the position shown. Even though the pressure in the duct **10** may remain longer than the time necessary for the reciprocation of the lower piston assembly, and the pressure throughout the system momentarily stabilizes, such pressure stabilization will insure a full return of the lower piston assembly to the left by virtue of the differential areas of the pistons **11** and **12**. When the valve **18** returns to the position shown, the system is ready for a subsequent operation.

Additionally shown in FIGURE 1, is a threaded plug **28** in the compliance chamber **26** which plug merely alters the volume thereof so as to provide an adjustment of the time delay in the pulse transmission. A further threaded plug **29** abutting the left end of the piston **11** provides a reset adjustment for the lower piston assembly and incidentally a physical stop therefore. Additionally since the forward stroke of the piston has no physical limit stop but is determined by the dynamics of the system, the plug **29** serves the additional function of providing a blow adjustment when the apparatus is used in an application where the work output occurs at a fixed displacement as in percussion printing. The pistons **11** and **12**, although they have been shown as separate abutting pistons, could equally well be joined. However, because of the greater ease of machining separate pistons and because separate pistons allow for minor mis-alignments in the cylindrical bores this method of fabrication has been preferred.

Because of the very rapid operation of this apparatus and the ever present deleterious effect of cavitation, the sump connection **22** instead of being conventionally connected to atmospheric pressure is supercharged to an initial pressure of 50 p.s.i. and the pipe **21** connected to a source of pressure of 650 p.s.i. to produce a pressure pulse of 600 p.s.i. With such pressure differences and employing hydraulic fluid having a viscosity of 50–100 S.S.U. (Sayboldt Seconds Universal) and a bulk compression modulus of 200–250,000 p.s.i. a complete reciprocation of the punch **14** of $\frac{3}{32}$ of an inch amplitude in 1.75 milliseconds with an initial punching force of 27 pounds can be achieved. Further exemplary parameters of the system include a compliance chamber having a volume of 1.75 cubic inches, a small piston of .250 inch diameter and .375 inch length, a large piston of .281 inch diameter and .422 inch length, and a piston rod connected to the larger piston of .062 inch diameter. Expressed in another fashion, the aspect ratio of any one piston is 1.5:1 and the effective piston area ratios including allowance for the piston rod is 1.2:1.

A better understanding of the operation of the pulse responsive operator can be had by reference to FIGURE 4 wherein there is shown, at least qualitatively, the forces acting on the pistons as well as the displacement of the piston assembly all referred to a common time base. In the upper portion of the drawing the dotted A and B curves represent the pressure forces respectively acting on pistons **11** and **12**, which forces are corrected for the area differences of the pistons as well as the area of the piston rod **13**. The intervening solid curve $(A+B)$ represents the net force on the pistons **11** and **12** which force curve, assuming a constant mass, then assumes the same configuration as an acceleration curve. The lowermost solid curve (D) represents the displacement of the piston assembly related to the same time axis as the force curves. Although not shown, a velocity curve could be constructed by either integration of the net force curve or differentiation of the displacement curve, although such curve is not so illuminating as those illustrated.

In FIGURE 4 it is assumed that at time zero, the valve **18** is opened and the pressure in duct **10** and against the piston **11** rises substantially instantaneously to source pressure, as is evidenced by the steep initial slope **35** of the dotted A curve. Once pressure is introduced into the system, this pressure remains substantially constant until the valve **18** is closed as is evidenced by the horizontal slope, section **36** of the A curve. With the pressure upon piston **11** at substantially source pressure the piston will accelerate to the right. The movement resulting from such acceleration will pump the fluid in end chamber **24** into the compliance chamber **26**, which pumping action, coupled with the fluid flow through the flow restrictor **27** builds the pressure in the compliance chamber **26** in accordance with the B curve of FIGURE 4. Inasmuch as the piston assembly can be considered as a unit responsive to the net force, the $A+B$ curve represents substantially the constant force on piston **11** subtracted from that force on the piston **12**. Thus it will be seen that the pressure rise in the compliance chamber is delayed, and when it does occur reaches a surge value approximately twice the source pressure while the piston is still moving toward the right and its maximum displacement. The superior pressure force accumulated in the compliance chamber overcomes the source pressure force to decelerate the assembly and accelerate it in the reverse direction. Were the system a perfectly elastic one, the piston assembly would bounce back to its initial state without loss. Fluid friction resulting in heat as well as less than perfect fluid seals prevents such elastic operation. For this reason, the piston **12** is made larger in effective area so that there will always be a positive restoration force, both during the time that source pressure is on the system and when the valve is closed to sump pressure. This effect is noted in the slope of the $A+B$ curve in its two stepped horizontal portions **37** and **38**, the greater of which (**37**) is the net force resulting from the 600 p.s.i. source pressure and the lesser (**38**) is the net force for 50 p.s.i. sump pressure. Thus there is always some net force to the left when the system is at rest. It will be noted that the acceleration due to the compressibility is effective to arrest the forward motion of the piston and to accelerate it in the reverse direction, followed by a complete restoration at a lesser rate by the area difference of the pistons because of system losses. Thus, of the total reciprocation time of 1.75 milli-seconds, only .5 m.s. are consumed in moving the piston to its full forward stroke (point **39** on the D curve), and the return stroke is somewhat slower. It is further significant that the forward stroke has no physical limit stop, its movement being determined solely by the dynamics of the system. The only physical stop is the plug **29** against which the piston **11** returns at substantially less than its maximum velocity so that violent impact is avoided in the system.

A series of cascaded pulse operators is shown in FIGURE 2 connected much in the fashion of a chain of monostable multi-vibrators, wherein an excursion of any one of the units in the chain produces a perturbation effecting the reciprocation of the next succeeding element in the chain. Although three orders are shown in the drawing connected in a closed ring, it will be apparent that any number of orders may be achieved with an endless variety of branching circuits so as to produce commutators or frequency dividers as is done in the multi-vibrator art. To assist in correlation between FIGURES 1 and 2, similar elements have been identified with the same numerical reference characters with the addition of the

alphabetical postscripts in FIGURE 2 indicative of the order.

Just as in the single operator of FIGURE 1, the cascaded operators in FIGURE 2 will undergo a rapid reciprocation when a pressure pulse is caused to occur in any one of the ducts **10***a*, **10***b*, or **10***c*. Whereas in FIGURE 1 the pressure impulse is produced by the movement of the valve **18** under the influence of the cam **20**, the pressure impulses in FIGURE 2 are also produced by the valves **18***a*, **18***b*, and **18***c* which valves, instead of being externally motivated, are connected to be actuated by the pulse operators themselves so that the operation of each pulse operator moves the corresponding valve **18** to provide the pressure impulse for the next succeeding operator. Specifically, when a pressure pulse appears in the duct **10***a* the pistons **11***a* and **12***a* in the first order will undergo a rapid reciprocation. The forward stroke of the piston rod **13***a* will drive the spool valve **18***b* so as to close the sump connection **22***b* and open the pressure duct **21***b* to the next succeeding duct **10***b* to create therein the requisite pressure surge or impulse to operate the succeeding pistons **11***b* and **12***b* in the same manner as in the FIGURE 1 embodiment. In order to prolong the pressure impulse to any succeeding operator a lost motion instrumentality is inserted between the impulse operators and their respective associated spool valves. In the first order of FIGURE 2, it will be observed that the piston rod **13***a* is positively coupled to the spool valve **18***b* only in the forward direction by virtue of the collar **40***a* which is integral with the piston rod **13***a*. Upon the return stroke of the piston rod **13***a*, the spool valve **18***b*, which is only slideably mounted thereon, will be free to return at its own rate as determined by spring **19***b* and a combination flow restrictor and check valve **50***b*, which valve is detailed in FIGURE 5 and has the general capability of providing unrestricted flow in one direction (as shown by the arrow) and a restricted or controlled flow in the direction opposite to the arrow. Thus, during the forward stroke of spool valve **18***b* fluid from sump connection **22***b* (at superatmospheric pressure) passes freely through the valve **50***b* and into the valve end chamber to permit unrestricted movement of the valve. In the reverse movement of valve **18***b*, the valve **50***b* acts as a flow restrictor so that a dashpot action results whereby the valve spool **18***b* returns under the influence of spring **19***b* at a rate controlled by the flow restriction of fluid through the valve **50***b* in the reverse direction to sump. Each of the valves **18***b*, **18***c*, and **18***a* has a similar lost motion apparatus so that each produces a pressure pulse for the next succeeding pulse-responsive operator to provide a chain reaction, the last of the valves **18***a* being connected back to the duct **10***a* to provide a closed loop, although such connection is merely an illustrative choice, as the chain can continue with or without closing for any number of stages, or one valve could produce a pulse for two succeeding valves so as to provide a branching circuit.

The combination valve **50**, detailed in FIGURE 5, is disposed in each of the successive orders with the unrestricted flow direction shown by the arrow in the circle in each order. For example, the valves **50***b* and **50***a* have unrestricted flow to the left, while the valve **50***c* has unrestricted flow to the right. The same arrow is included in FIGURE 5 wherein it will be readily apparent that free flow to the left will result upon compression of spring **51** to permit free flow of fluid around the poppet **52**. Flow contra to the arrow will seal the poppet **52** in seat **53** whereby flow will be reduced to that permitted by the orifice **52***a* through poppet **52**, which orifice although shown as a fixed dimension could readily be made adjustable.

Although it may be assumed that the cascaded operators in FIGURE 2 are continuously running, it is well to reflect as to the initial state of the apparatus before the application of any pressure to the system. In such state the positions of the successive operators and their respective attached valves would normally reside in the position shown, although the successful operation of the apparatus is not dependent thereon. Whatever respective positions the operators and valves occupy initially, upon application of super-atmospheric pressure to the lines **22***b*, **22***c*, and **22***a* to supercharge the system, the various elements will occupy the positions shown in FIGURE 2 by virtue of the superior area of the pistons **12***a*, **12***b*, and **12***c*. If now the high pressure is applied to the lines **21***a*, **21***b*, and **21***c*, it will be blocked from influencing the pressure status of any of the ducts **10***a*, **10***b*, or **10***c* so that no motion in the apparatus will result therefrom. If, however, any one of the externally-led piston rods **13***a*, **13***b*, or **13***c* is afforded an external displacement sufficient to shift the respectively connected valve, a high pressure impulse will be produced in one of the ducts **10***a*, **10***b*, or **10***c* to initiate a cycling of the apparatus which once started will continue to operate so long as the requisite pressures are applied. An alternative method of starting the sequence of operation is to apply the high pressure first to all of the lines **21***a*, **21***b*, and **21***c* and then to apply the supercharge pressure which being suddenly applied will act to move one or more of the pulse operators in the chain and start the reaction, the first of the valves to react will pass the high pressure to the next succeeding operator which will then continue the action.

As in FIGURE 1, the piston rods **13***a*, **13***b*, and **13***c* are led external to the housing so that a succession of mechanical outputs are provided, as for example seriate punching. Equally well, these piston rods could be connected to any external work circuit requiring this extremely rapid reciprocatory movement.

As will be remembered with respect to the operation of the cascaded pulse operators of FIGURE 2, the outward excursion of any one of the valves **18***a*, **18***b*, or **18***c* produces a pressure surge which is fed to the next succeeding operator in the chain to effect operation thereof. In FIGURE 3 a further embodiment is disclosed wherein a complete outward and return movement of the valve is required before a pressure surge is passed to the next succeeding valve, the pressure surge being stored in an added interstage compliance chamber. In this further embodiment a longer cycling time is effected and no overlap in the operation of successive elements in the chain is had. Again the elements corresponding to the same elements in FIGURES 1 and 2 will be identified by the same numerical reference characters and the postscripts "*x*," "*y*" and "*z*" will be appended thereto to denote the corresponding orders in the chain of FIGURE 3.

Just as in FIGURES 1 and 2 and particularly in FIGURE 2 the individual stage operations in FIGURE 3 operate in response to a single applied pressure impulse which is delayed in its transmission to one side of the operator to effect a rapid reciprocation. In FIGURE 1 the pulse was produced by a cam-actuated valve, whereas in FIGURE 2 the pressure pulse was produced by the forward excursion of the valve connected to the preceding stage operator. In the FIGURE 3 structure the pressure pulse is produced by porting high pressure into an auxiliary compliance chamber during the forward stroke of any one valve and then porting the fluid in that chamber to the next succeeding pulse operator upon the return of the valve. By this hydraulic circuitry the compressibility of the fluid is doubly exploited, both to delay the pulse to the operator and to produce the pulse for the next succeeding operator.

If in FIGURE 3, the pipes **21***x*, **21***y*, and **21***z* are connected to a source of high pressure and a pressure pulse produced in the duct **10***x* of the first stage, the pistons **11***x* and **12***x* will be reriprocated in the same fashion as the foregoing embodiments. Upon the advance stroke thereof, the valve **18***y* will be moved so as to port the high pressure duct **21***y* to the auxiliary compliance chamber **30***y* via the port **32***y* and the fluid therein will be compressed to a

degree compatible with the compressibility of the fluid and the magnitude of the source pressure. Upon the return stroke of the valve **18***y*, the compliance chamber **30***y* will be ported to the duct **10***y* of the next succeeding operator and the compressed fluid will expand to produce the requisite pressure impulse for the operation of the pistons **11***y* and **12***y*. Inasmuch as none of the auxiliary compliance chambers **30***x*, **30***y*, or **30***z* is ported to sump by operation of the valves **18**, provision must be made to relieve the pressure therein if continued cyclical operation is to be effected. There has therefore been provided, in each of the auxiliary compliance chambers **30***x*, **30***y*, and **30***z*, the respective bleeds **33***x*, **33***y*, and **33***z* which permit the controlled escape of fluid to sump so as to diminish the pressure therein in anticipation of a subsequent pressure surge of source pressure, the bleeds having a time constant such that they will not substantially interfere with the pulse response but will provide an adequate pressure bleed for a succeeding cyclical operation. Absent these purges or bleeds, the chain of operators would undergo an initial cycle of operation and stop as the pressure in the compliance chambers would be substantially at source pressure and would not be receptive to further source pressure charging to provide a pulse for operation of the next succeeding operator.

As in the cascaded operators of FIGURE 2, the operators of FIGURE 3 include the same lost motion apparatus between the valve spools **18***y*, **18***z*, and **18***x* and their associated piston rods as well as the valves **50***y*, **50***z*, and **50***x* connected between the end chambers of the respective valves **18***y*, **18***z*, and **18***x* and the sump connections **22***y*, **22***z*, and **22***x*, which sump connections are, as in the preceding embodiment, supercharged. Thus the return stroke of any valve is controlled by the dashpot action of the valves **50***x*, *y* or *z*. Inasmuch as the pressure impulse for any one operator is not produced until the preceding valve **18***x*, *y*, or *z* returns, and since the valve return rate is controlled or controllable, it is possible to insert in the FIGURE 3 embodiment a variable time delay between adjacent stages such that an almost infinite variety of cycling arrangements is available through the simple expedient of providing different time delays between adjacent stages. Thus, for example, a cycle could be achieved with three cascaded operators of (1) very rapid action of the first operator, followed by (2) a long delay in the second, and (3) a medium length delay in the third operator.

In all of the foregoing embodiments the compressibility of fluid has been advantageously employed to provide a pressure impulse delay, which delay provides the energy storage for the restoration of the apparatus, and because of the relatively high modulus of compressibility of available standard fluids the speed of operation is extremely rapid. In fact, by suitable selection of a fluid the operating speed can be adjusted commensurate with the needs of the associated equipment, so that in many applications where intervening mechanical motion is required, delays occasioned by the mechanical apparatus can now be eliminated to the end of improving the overall efficiency of an integrated machine combining both electronics and mechanical apparatus.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A fluid apparatus comprising, a plurality of fluid pressure pulse responsive operators each adapted to undergo a single forward and return stroke in response to a single pressure impulse applied individually thereto, a valve connected to each of said operators and operative responsive to the movement of the connected operator to produce a pressure impulse, and means connecting each of said valves to one of said pulse responsive operators so as to form thereby a chain of operators, wherein each operator by its movement controls the production of a pressure impulse to effect the operation of the next succeeding connected pulse operator in the chain.

2. A fluid apparatus comprising a plurality of seriately disposed fluid pressure impulse responsive operators each adapted to undergo a single forward and return stroke in response to a single pressure impulse individually applied thereto; a fluid pressure supply line; a fluid return line; a plurality of ducts each individually connected to one of said operators; and a valve mechanically connected to each of said operators and fluid coupled between said fluid pressure line, said fluid return line, and a duct of an operator next disposed in said seriate disposition of operators, and operative responsive to the movement of the connected operator to alternately expose said duct to said fluid pressure line and said fluid return line so as to produce in each said duct a fluid pressure impulse in response to the movement of the respective preceding operator in said seriate disposition of operators.

3. A fluid apparatus comprising a plurality of seriately disposed fluid pressure impulse responsive operators each adapted to undergo a single forward and return stroke in response to a single pressure impulse individually applied thereto; a fluid pressure supply line; a plurality of ducts each individually connected to one of said operators; a plurality of fixed volume chambers; and a valve mechanically connected to each of said operators and fluid coupled between said pressure line, one of said ducts, and one of said chambers, and operative responsive to the forward movement of the connected operator to expose the coupled chamber to said pressure supply line to compress the fluid therein, and upon the return stroke to expose the said duct to the compressed fluid in said chamber to produce in said duct a pressure impulse for the operation of the operator associated therewith, whereby each operator is successively controlled by the operation of the preceding operator in the seriate disposition.

4. In a fluid apparatus including a plurality of cascaded stages connected such that each stage effects the operation of the next succeeding stage, the combination in each stage of a single input duct; a fixed volume chamber; a fluid flow restrictor connecting said duct and said chamber; a first cylinder connected to said duct; a first piston reciprocable in said first cylinder; a second cylinder connected to said chamber; a piston reciprocable in said second cylinder and abutting the said first piston; a piston rod connected to said piston in said second cylinder and having an enlarged abutment thereon; a spool valve slideably mounted upon said piston rod and having a spring urging said valve against said abutment; a fluid pressure supply line; a fluid return line; a signal output duct; means connecting said valve to said pressure line, said return line, and said signal output duct, so that said duct is alternately connected to said supply and return line by movement of said valve spool; and means for controllably restraining the movement of said valve in its spring-urged direction.

5. In a fluid apparatus including a plurality of cascaded stages connected such that each stage effects the operation of the next succeeding stage, the combination in each stage of a signal input duct; a first fixed volume chamber; a fluid flow restrictor connecting said duct and said chamber; a first cylinder connected to said duct; a first piston reciprocable in said first cylinder; a second cylinder connected to said chamber; a piston reciprocable in said second cylinder and abutting said first piston; a piston rod connected to said second piston and having an enlarged abutment thereon; a spool valve slideably mounted upon said piston rod and having a spring urging said valve against said abutment; a second fixed volume chamber; a fluid supply line; a signal output duct; and means connecting said valve with said duct, said second chamber, and said line, whereby movement of said valve alternately connects said chamber to said signal output

duct and to said supply line so to compress the fluid in said chamber and to release the compressed fluid into the said duct to produce a pressure surge therein.

6. The apparatus as defined in claim 5 wherein means are provided for controllably arresting the movement of said spool valve in its spring-urged direction.

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