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Morris et al.

[11] **3,710,815**

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[54] **PNEUMATIC OSCILLATOR APPARATUS**

[76] Inventors: **Carl H. Morris,** 2615 Ridge Avenue; **Henry N. Oliver,** 2321 Cumberland Street, both of Rockford, Ill. 61103

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[52] **U.S. Cl.**.....**137/106,** 137/624.14

[51] **Int. Cl.**.....**F15b 13/02**

[58] **Field of Search**.....137/624.14, 106, 102

[56] **References Cited**

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Primary Examiner—Alan Cohan

Attorney—McCanna, Morsbach, Pillote & Muir

[57] **ABSTRACT**

A pneumatic oscillator apparatus having a pressure operated five-way auxiliary valve for reversibly operating a reciprocable fluid operated device, a pressure operated five-way main valve for reversibly applying fluid pressure to the five-way auxiliary valve to reversibly operate the latter, and a pair of three-way pressure operated pilot valves for reversibly operating the main valve, which pilot valves are operated in response to the pressure conditions at the controlled outlet ports of the main valve. Pneumatic control means are provided for regulating exhaust of fluid pressure from the controlled outlet ports of the main valve to control the dwell time of the main valve at each end of its stroke, and to thereby control the frequency of the pneumatic oscillator. An adjustable pressure regulated supply is provided for the auxiliary valve to enable adjustment of the pressure applied to the fluid operated device independent of the pressure applied to the pneumatic oscillator, and additional pneumatic controls are provided for regulating exhaust of fluid from the auxiliary valve to enable independent adjustment of the rate of movement of the fluid operated device in either direction.

9 Claims, 8 Drawing Figures

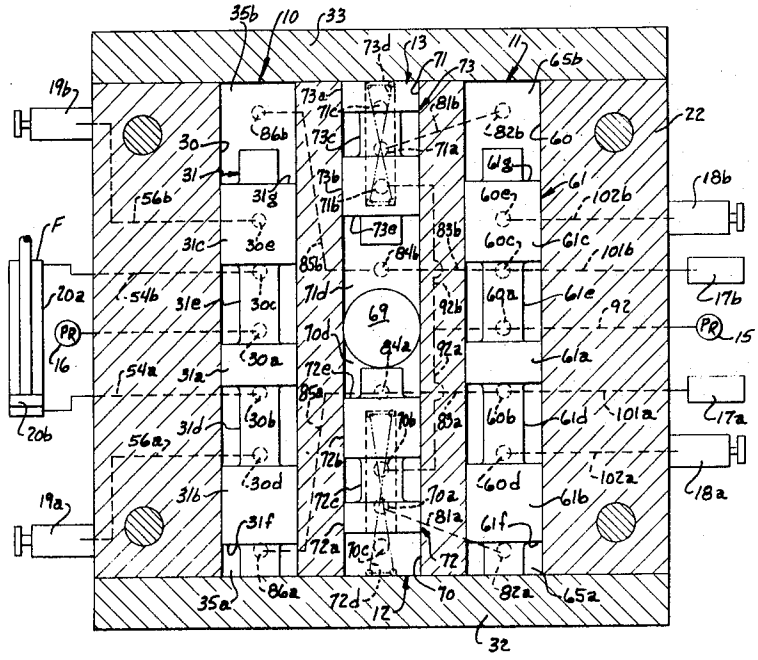


Fig. 2.

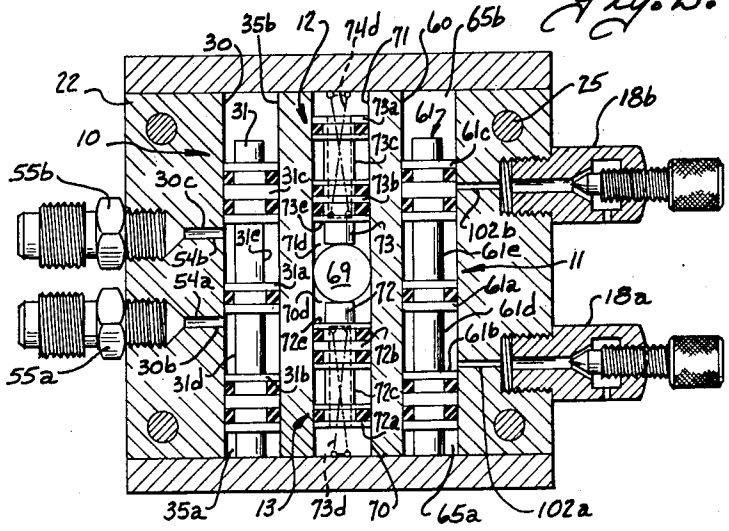
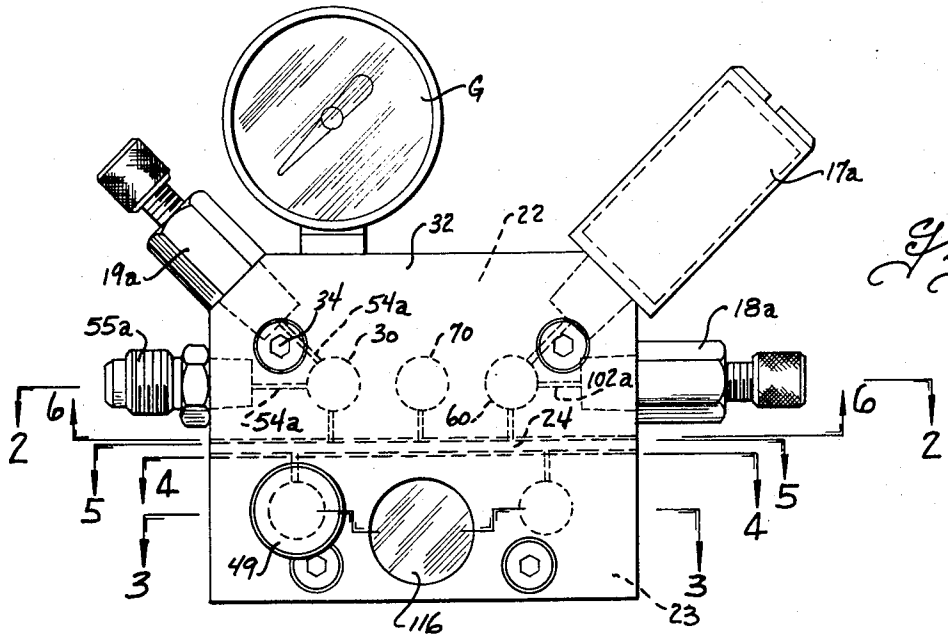


Fig. 1.



Inventors
Carl H. Marvin
Henry N. Oliver

By
McCanna, Morsbach, Pillote & Muir
Attorneys

Fig. 3.

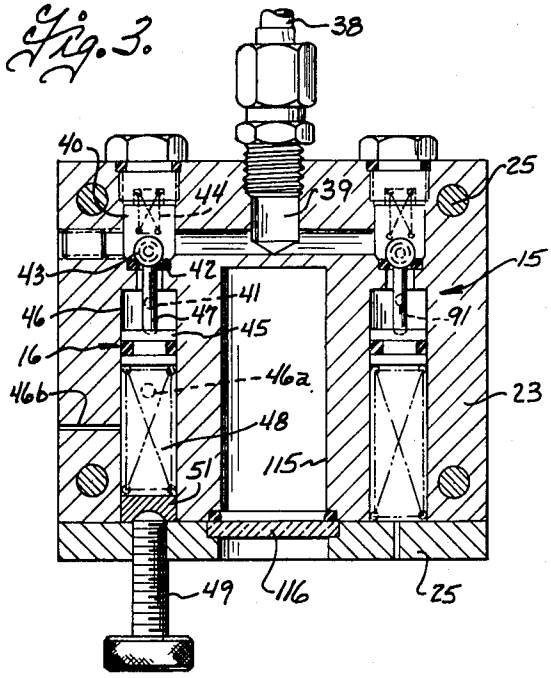


Fig. 4.

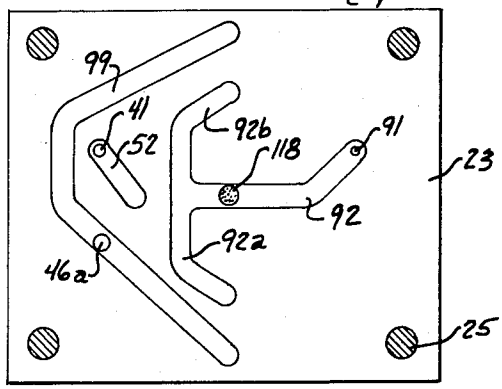


Fig. 5.

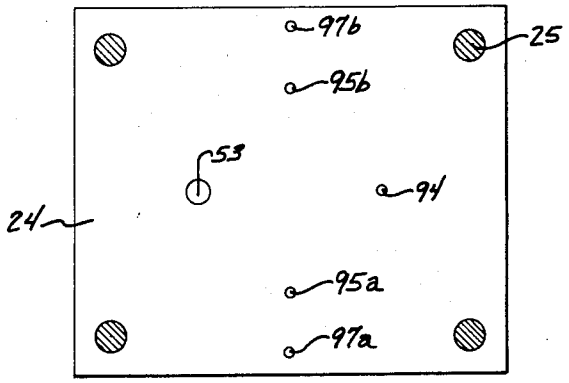
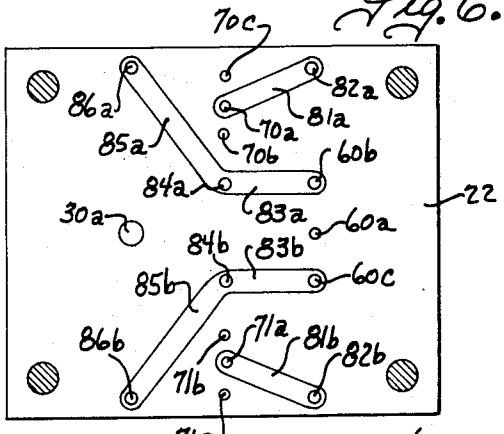


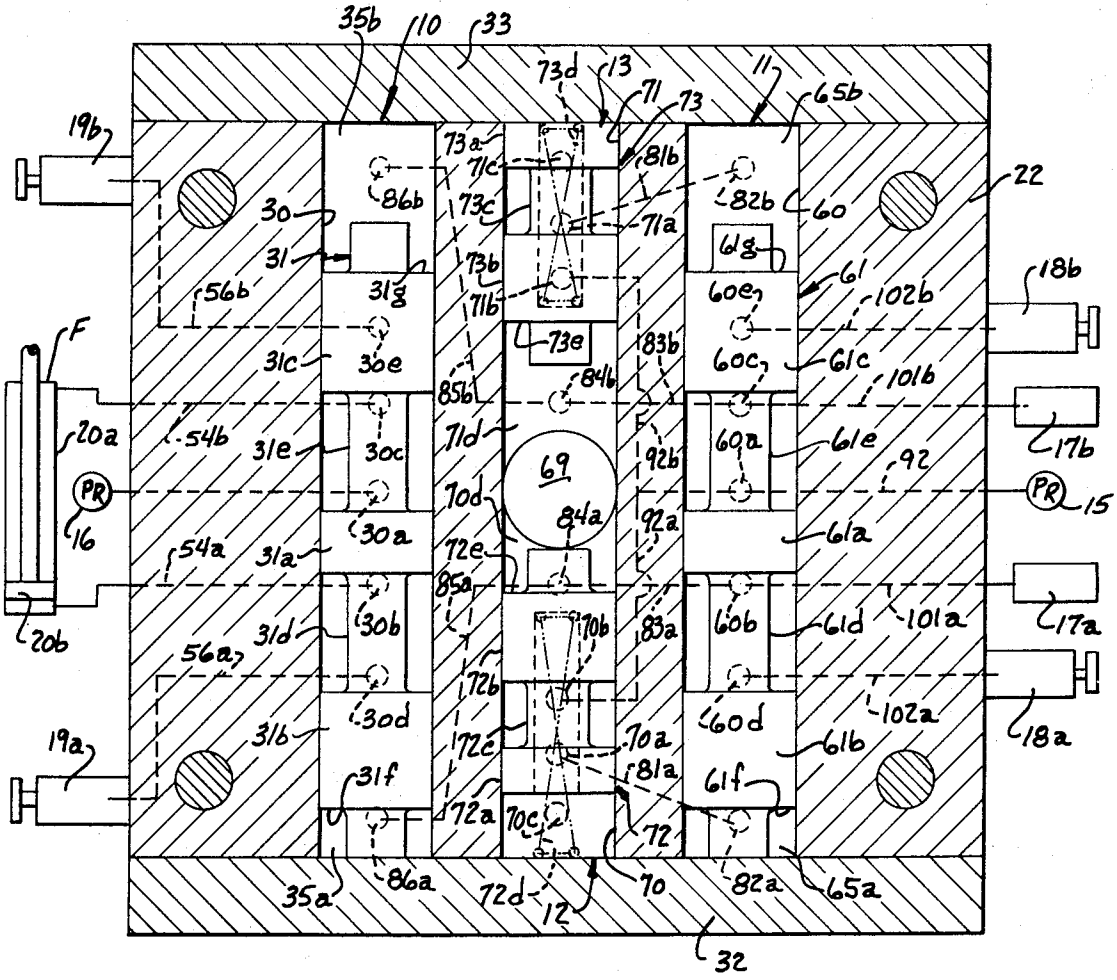
Fig. 6.



Inventors
Carl H. Marrin
Henry N. Oliver

By
McCanna, Morsbach, Pillsb. & Murr
Attorneys

Fig. 7.



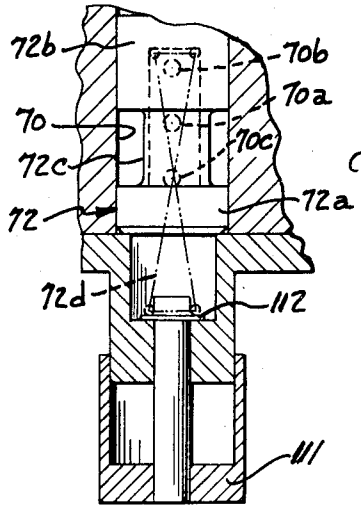


Fig. 8.

Inventors
Carl H. Morris
Henry N. Oliver

By
McCanna, Morsbach, Pillote & Muir
Attorneys

PNEUMATIC OSCILLATOR APPARATUS

BACKGROUND AND SUMMARY OF THE INVENTION

Various different arrangements have heretofore been proposed to provide a self-cycling control for fluid motors of the reciprocating type to cause automatic reciprocation of the motor. In some arrangements such as disclosed in U.S. Pat. No. 2,512,730, the reversing valve is mechanically operated by a mechanism responsive to the position of the reciprocating fluid motor. In other arrangements such as shown in U.S. Pat. No. 2,550,723, fluid pressure from the reciprocating motor is directly applied to the flow reversing valve spool to reverse the position of the spool when the piston reaches the end of its stroke. In still other arrangements such as shown in U.S. Pat. Nos. 1,952,690 and 3,385,166, pressure from the reciprocating motor is applied through a pilot valve arrangement to the main flow reversing valve to reversibly operate the main valve in accordance with the pressure conditions in the reciprocating fluid motor.

The pneumatic oscillator apparatus of the present invention is arranged to reversibly apply fluid pressure to a fluid operated device without the use of any mechanical linkage mechanism responsive to the position of the fluid operated apparatus and independent of the fluid pressure conditions in the fluid operated device. The pneumatic oscillator also includes adjustable controls for adjusting the frequency of the oscillator apparatus together with additional adjustable controls for adjusting the rate of movement of the fluid operated device.

In general, the pneumatic oscillator apparatus includes an auxiliary valve having an independent fluid supply and which is pressure operated between first and second positions to reversibly apply fluid pressure to the fluid operated device. The fluid oscillator also includes a pneumatically operated timer having a five-way main flow reversing valve arranged to reversibly apply fluid pressure to the auxiliary valve to actuate the latter, and first and second three-way pilot valves which are operated in response to the pressure conditions at the controlled outlet ports of the main flow reversing valve and which pilot valves reversibly apply fluid pressure to opposite ends of the main valve to reversibly operate the latter. Fluid controls are provided for regulating the rate of exhaust of fluid pressure from the main valve to thereby regulate the dwell time of the main valve in each of its positions, and additional fluid controls are provided to control exhaust of fluid pressure from the auxiliary valve to adjust the rate of movement of the fluid operated device. The fluid oscillator is accordingly adjustable to vary the pressure applied to the fluid operated device as well as the frequency and rate of movement of the fluid operated device.

The pneumatic timing apparatus of the oscillator apparatus also includes an improved pilot valve arrangement employing a pair of three-way pressure operated pilot valves which are arranged to reversibly apply fluid pressure to opposite ends of the main valve in accordance with the pressure conditions at the controlled outlet ports of the main valve. The pneumatic timer apparatus can be utilized to directly operate a reciprocable fluid operated device.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of a pneumatic oscillator apparatus embodying the present invention;

FIG. 2 is a horizontal sectional view taken on the plane 2—2 of FIG. 1 and illustrating the pneumatically operated valve arrangement;

FIG. 3 is a horizontal sectional view taken on the plane 3—3 of FIG. 1 and illustrating the pressure regulators for the fluid oscillator apparatus;

FIG. 4 is a horizontal sectional view taken on the plane 4—4 of FIG. 1;

FIG. 5 is a horizontal sectional view taken on the plane 5—5 of FIG. 1;

FIG. 6 is a horizontal sectional view taken on the plane 6—6 of FIG. 1;

FIG. 7 is a diagrammatic view illustrating the pneumatic oscillator apparatus; and

FIG. 8 is a fragmentary sectional view illustrating a modified embodiment.

The pneumatic oscillator apparatus of the present invention in general includes an auxiliary pressure operated flow reversing valve **10** for reversibly applying fluid pressure to a fluid pressure operated device F; a main pressure operated flow reversing valve **11** for reversibly applying pressure to the auxiliary valve **10** to reversibly operate the same; and a pair of pressure operated pilot valves **12** and **13** which are responsive to the pressure at the controlled outlet ports of the main valve **11**, and which reversibly apply fluid pressure to the main valve **11** to effect oscillation of the same. The main control valve and pilot valves **12** and **13** form a pneumatic timing apparatus and fluid pressure is supplied to the main valve **11** and pilot valves **12** under the control of a pressure regulator **15**. A separate adjustable pressure regulated supply including pressure regulator **16** is provided for supplying fluid under pressure to the auxiliary valve **10** in order to enable adjustment of the pressure supplied to the fluid operated device F independent of the pressure utilized to operate the oscillator. Accumulators **17*a*** and **17*b*** (FIG. 7) communicate with the controlled outlet ports of the main valve **11** and flow regulators **18*a*** and **18*b*** are provided to regulate exhaust of fluid from the main valve to vary the frequency of the pneumatic oscillator. Additional flow regulators **19*a*** and **19*b*** are provided for regulating exhaust of fluid from the auxiliary valve **10** to enable selective adjustment of the rate of movement of the fluid operated device F controlled by the auxiliary valve. The fluid operated device F may be any suitable device which it is desired to cyclically operate or test and may, for example, comprise cylinder **20*a*** and piston **20*b*** diagrammatically shown in FIG. 7.

The auxiliary valve **10**, main valve **11** and pilot valves **12** and **13** are conveniently mounted in a valve body **22** and the pressure regulators **15** and **16** are conveniently mounted in a second valve body **23**. A ported gasket **24** is disposed between the bodies and the bodies are conveniently joined together by bolts **25**.

The auxiliary valve **10** is a five-way pressure operated valve and comprises a bore **30** formed in the body **23** and a valve spool **31** slidable in the bore. As diagrammatically shown in FIG. 7, the auxiliary valve bore **30** has an auxiliary inlet port **30*a***, first and second auxiliary controlled ports **30*b*** and **30*c***, and first and second auxiliary discharge ports **30*d*** and **30*e***. The first

and second auxiliary controlled ports **30***b* and **30***c* are located intermediate the inlet port **30***a* and a respective one of the auxiliary discharge ports **30***d* and **30***e* and the valve member **31** has passage means operative to alternately connect the controlled outlet ports **30***b* and **30***c* to the auxiliary inlet and discharge ports. Valve **31** is of the spool type and has spaced sealing lands **31***a*, **31***b* and **31***c* forming a sliding seal with the bore **30** and defining first and second valve passages **31***d* and **31***e* which are operative in a first position of the valve member shown in FIG. **7**, to connect the auxiliary controlled port **30***b* with a respective discharge port **30***d*, while connecting the auxiliary controlled port **30***c* with the auxiliary inlet port **30***a*, and operative in a second position of the valve member **31** to reverse the application of fluid pressure to the auxiliary controlled ports **30***b* and **30***c*. As will be noted, the pressures in valve passage **31***d* act on equal and relatively opposite areas of lands **31***a* and **31***b* while the pressures in valve passage **31***e* act on equal and relatively opposite areas of lands **31***a* and **31***c* so that the fluid pressure being controlled by the valve **10** does not produce pressure unbalance on the valve. In other words, the valve spool **31** is of the balanced type and is pressure operated from one position to the other in response to pressure conditions acting on first and second end faces **31***f* and **31***g* thereof. For this purpose, the ends of the valve bore **30** are closed as by plates **32** and **33** which are secured to the valve blocks **22** and **23** as by fasteners **34** (FIG. **1**). Plates **32** and **33** define first and second auxiliary pressure chambers **35***a* and **35***b* that communicate with the end faces **31***f* and **31***g* respectively.

The pressure regulator **16** which controls application of fluid pressure to the auxiliary valve inlet port **30***a* is shown in FIG. **3**. In the embodiment illustrated, the auxiliary valve is arranged to apply pneumatic pressure to the fluid operated device **20***a*, **20***b*, it being understood that the auxiliary valve could control the flow of hydraulic fluid to the fluid operated device, if desired. As shown in FIG. **3**, air under pressure is supplied from a supply line **38** to a line pressure passage **39** in the valve body **23**. The pressure regulator has a supply chamber **40** that communicates with the passage **39** and a regulated outlet passage **41**. In the embodiment disclosed, the controlled outlet passage communicates with the bore **46** at a level above the section plane **3**—**3**. However, to facilitate description, the controlled outlet passage is shown in phantom in FIG. **3**. A valve seat **42** is located between the supply chamber **40** and the controlled outlet passage **41** and a valve member **43** cooperates with the seat **42** to regulate flow therethrough. The valve **43** can conveniently be in the form of a ball valve that is yieldably urged to its closed position by a light spring **44**. A pressure responsive piston **45** is slidably in the bore **46** and has one side exposed to the pressure at the regulated outlet **41** and the other side exposed to atmosphere through a vent passage **46***a*, also shown in phantom in FIG. **3**. An actuating rod **47** on the piston **45** is arranged to engage the valve member **43** to move the latter to its open position, and a pressure regulator spring **48**, relatively stronger than the spring **44**, engages the rear side of the piston **45** to yieldably urge the valve member to its open position. The pressure applied by the spring **48** is adjustable by means of a screw **49** that engages an adjustable stop **51** at the rear end of the spring **48**, to regulate the pressure maintained at the regulated outlet port **41**. As will be seen, the pressure at the regulated outlet port acts on the piston **45** and urges the piston in a direction to compress the spring **48** and, when the pressure at the regulated outlet reaches the preselected pressure, the piston compresses the spring sufficient to allow valve **43** to move toward the seat to throttle flow and thereby regulate pressure. As shown in FIG. **4**, the controlled port of regulator **16** is conveniently in the form of a bore that extends to the upper face of the valve block **23** and which communicates through a lateral passage **52** with a port **53** in the gasket **24**. The auxiliary inlet port **30** *a* comprises a bore in the valve body **23** that intersects the auxiliary bore **30** at the desired location and which communicates through port **53** and passage **52** with the regulated port **41** of the regulator **16**. A pressure gauge G (FIG. **1**) is provided and arranged to communicate with the auxiliary inlet port **30***a* to facilitate adjustment of the pressure applied to the auxiliary valve **10**.

As shown in FIG. **2**, the controlled outlet ports **30***b* and **30***c* of the auxiliary valve communicate through laterally extending passages **54***a* and **54***b* with fittings **55***a* and **55** *b* that are adapted for connection to the fluid operated device F. Flow regulators **19***a* and **19** *b* comprise needle valves which are connected through passages **56***a* and **56***b* respectively diagrammatically shown in FIG. **7** with the auxiliary discharge ports **30***d* and **30***e* respectively. As best shown in FIG. **1**, the flow control valves **19***a* and **19***b* are conveniently mounted so as to extend generally radially of the auxiliary valve bore **30** and the passages **56***a* and **56***b* can be formed by merely drilling passages that intersect the auxiliary valve bore **30** at the proper locations. Flow regulator valves **19***a* and **19***b* regulate the rate of flow of fluid from the auxiliary controlled ports **30***b* and **30***c*, when the auxiliary valve member **31** is positioned to communicate the respective auxiliary controlled port with its associated discharge port. In this manner, flow control devices **19***a* and **19***b* can be individually adjusted to regulate the rate of movement of the fluid operated device F in the first and second directions of the latter.

The main valve **11** and pilot valves **12** and **13** are part of an adjustable pneumatic timer for reversibly applying fluid pressure to the auxiliary pressure chambers **35***a* and **35***b* to reversibly operate the auxiliary valve at a rate controlled by the timer. Main valve **11** comprises a main valve bore **60** formed in the valve body **23** and a main spool valve member **61** slidable in the main bore. The main valve is of the five-way flow reversing type and includes a main valve inlet **60***a*, first and second main controlled ports **60***b* and **60***c*, and first and second main discharge ports **60***d* and **60***e*. The main valve ports are shown in phantom in FIG. **7** to illustrate their position axially of the main valve bore, it being understood that the main valve ports are located at different positions circumferentially of the bore **60**, from the positions diagrammatically shown in FIG. **7**. Main controlled ports **60***b* and **60***c* are axially located intermediate the main inlet **60***a* and the respective main discharge ports **60***d* and **60** *e* and the spool valve **61** is arranged to alternately connect the main controlled ports **60***b* and **60***c* with the main inlet and discharge ports. In particular, spool valve member **61** has an in-

termediate land 61*a* and first and second end lands 61*b* and 61*c* which form a sliding seal in the bore 60 and define first and second valve passages 61*d* and 61*e*. Spool valve 61 is also of the balanced type previously described in connection with auxiliary valve 31, and valve 61 is operative in a first position to communicate the main controlled port 60*b* with the main discharge port 60*d* while communicating the other main controlled port 60*c* with the main inlet port 60*a*. When the valve 61 is moved to its other position, the application of fluid pressure to the controlled ports 60*b* and 60*c* is reversed. The ends of the main valve bore 60 are also closed by the plates 32 and 33 to form first and second main pressure chambers 65*a* and 65*b* that communicate with main end faces 61*f* and 61*g* respectively on the main valve member.

The first and second pilot valves 12 and 13 include pilot valve bores 70 and 71 conveniently formed at opposite ends of a single bore having a plug 69 intermediate its ends. Pilot valves 12 and 13 are each of the three-way type and the first and second pilot valves 70 and 71 respectively have first and second pilot controlled ports 70*a*, 71*a*; first and second pilot inlet ports 70*b*, 71*b*; and first and second pilot discharge ports 70*c* and 71*c*. First and second pilot valve spools 72 and 73 are slidable in the pilot valve bores 70 and 71 and have spaced lands 72*a*, 72*b* and 73*a*, 73*b* respectively defining pilot valve passages 72*c* and 73*c*. The pilot valve spools 72 and 73 are yieldably urged by springs 72*d* and 73*d* to a first position shown in FIG. 2 communicating the respective controlled pilot port with the pilot inlet, and the pilot valves 72 and 73 have a pressure motive face 72*e* and 73*e* on their ends exposed to fluid pressure in pilot pressure chambers 70*d* and 71*d* respectively. As best shown diagrammatically in FIGS. 6 and 7, the first and second controlled pilot ports 70*a* and 71*a* are respectively connected through passages 81*a* and 81*b* and 82*a*, 82*b* with the first and second main valve pressure chambers 65*a* and 65*b*, so that the first and second pilot valves are respectively operable to reversibly apply fluid pressure to the first and second main pressure chambers to reversibly operate the main valve 11. Fluid under pressure from the main controlled ports is also applied through passages 83*a*, 83*b* and 84*a*, 84*b* to the first and second pilot pressure chambers 70*d* and 71*d* respectively to pressure operate the pilot valves from their first position to a second position when the pressure at the respective main controlled port reaches a preselected value. The pressure at the main controlled ports 60*b* and 60*c* is also applied through passages 85*a*, 85*b* and 86*a*, 86*b* to the auxiliary valve pressure chambers 35*a* and 35*b* respectively, to reversibly operate the auxiliary valve.

Fluid under pressure is supplied to the main inlet port 60*a* and to the pilot inlet ports 70*a* and 71*a* under the control of the pressure regulator 15. As shown in FIG. 3, regulator 15 is conveniently made similar in construction to regulator 16 and further detailed description is deemed unnecessary. Regulator 15, however, can be of the preset type having a non-adjustable regulator spring operative to maintain a preselected pressure at the regulated outlet port shown in phantom at 91 in FIG. 3. Pressure at the regulated outlet port is applied through a passage 92, conveniently formed at the upper side of the valve block 23, as shown in FIG. 4, and through port 94 (FIG. 5) in the gasket 24 to the main inlet port 60*a*. Pressure at the regulated outlet port is also applied through branch passages 92*a* and 92*b*, and through ports 95*a* and 95*b* in gasket 24 (FIG. 5), to the first and second pilot inlet ports 70*b* and 71*b* respectively. The pilot exhaust ports 70*c* and 71*c* are interconnected through ports 97*a* and 97*b* in the gasket 24 to a common exhaust passage 99 (FIG. 4), conveniently formed at the upper side of the valve body 23. As shown in FIG. 4, exhaust passage 92 is also connected through passage 46*a* with the regulator bore 46 and exhausts to atmosphere through vent 46*b*.

The aforementioned first and second accumulators 17*a* and 17*b* respectively communicate with the first and second main controlled ports 60*b* and 60*c* through passages 101*a* and 101*b*. Flow regulators 18*a* and 18*b*, shown in the form of needle valves in FIG. 2, communicate through passages 102*a* and 102*b* with the first and second main discharge ports 60*d* and 60*e* respectively to regulate flow of fluid therefrom. Thus, the flow regulator 18*a* operates to regulate the flow of fluid from the accumulator 17*a* when the main valve is in its first portion communicating the main controlled port 60*b* with the main discharge port 60*d*, and flow regulator 18*b* operates to regulate the flow of fluid from accumulator 17*b* when the main valve is in its second position communicating main controlled port 60*c* with main discharge port 60*e*.

In the above-described pneumatic oscillator apparatus, the pneumatic oscillator will automatically begin operation when pressure is applied to the main inlet line 38. In the modification shown in FIG. 8, the oscillator apparatus is made selectively operable under the control of an actuator member 111. As shown in FIG. 8, actuator 111 controls a shiftable abutment 112 that engages the end of one of the pilot biasing springs 72*d*. With this arrangement, biasing of the pilot spool 72 to its first position can be selectively controlled to thereby control operation of the pneumatic oscillator.

An air lubricator is preferably provided and as shown in FIG. 3 includes a lubricant chamber 115 formed in the valve block 23 and closed at one end by a sight glass 116 to enable visual inspection of the lubricant level. A wick 118 extends from the lubricant chamber into the pressure inlet passage 92 (see FIG. 4) to introduce lubricant into the air passing to the timer.

OPERATION

From the foregoing it is thought that the construction and operation of the pneumatic oscillator apparatus will be readily understood. In the absence of fluid pressure applied to the pneumatic oscillator, the pilot valve spools 72 and 73 will assume their inner positions shown in FIG. 2 under the bias of springs 72*d* and 73*d*. For purpose of describing the operation, it will be assumed that the main and auxiliary valve spools 61 and 31 respectively are in the position shown in FIG. 2, previously described as their first position. In the first position of the auxiliary valve, auxiliary inlet port 30*a* communicates with the auxiliary controlled port 30*c* to apply fluid pressure to the fluid pressure operated device 20 to move it to the position shown in FIG. 7. When the main valve was in its first position, fluid under pressure from the main inlet port 60*a* is applied through main controlled port 60*c* to the second pilot

pressure chamber **71***d* to move the second pilot valve to its raised position shown in FIG. 7. Fluid under pressure is also supplied from the second main controlled port **60***c* to the second accumulator **17***b* so as to charge the accumulator to the pressure determined by regulator **15**.

When the second pilot spool **73** moves to its second position shown in FIG. 7, it communicates the second pilot controlled port **71***a* with the second pilot discharge port **71***c* so as to vent the second main pressure chamber **65***b* to atmosphere. The first pilot valve spool **72**, however, remains in its raised position and communicates the first pilot controlled port **70***a* with the first pilot inlet **70***b* so as to apply fluid pressure to the main pressure chamber **65***a* to thereby move the main valve spool to its second position. When the main valve spool moves to its second position, it communicates the second main controlled port **60***c* with the second main discharge port **60***e* to thereby vent the accumulator **17***b* to atmosphere through the flow regulator **18***b*. Simultaneously, the first main controlled port **60***b* is communicated with the main inlet **60***a* so as to charge accumulator **17***a* and simultaneously apply pressure to the first pilot spool **72** to move the latter to its second position. The main valve spool will remain in its second position until the accumulator **17***b* has discharged through the flow regulator **18***b* to a value sufficient to allow the second pilot spool to move to its first position under the bias of spring **73***d*. When the second pilot spool moves back to its first position, it operates to apply fluid pressure to the second main pressure chamber **65***b* to move the main valve back to its first position. The main valve will thus dwell in its first and second positions for a time interval determined by the time required to bleed the pressure from the respective accumulators **17***a* and **17***b* through the associated adjustable flow regulators **18***a* and **18***b*. Obviously, different size accumulators can be used and the flow regulators can be adjusted so that the dwell time of the main valve in either of its first or second positions can be adjusted throughout a wide range to thereby adjust the frequency of the oscillator. Moreover, the flow regulators **18***a* and **18***b* can be adjusted to different positions to provide different dwell times for the main valve in its first and second positions.

As the main valve moves between its first and second positions it also reversibly applies fluid pressure to the pressure chambers **35***a* and **35***b* of the auxiliary valve to reversibly actuate the auxiliary valve. As will be seen, the frequency of oscillation of the auxiliary valve can be controlled independent of the pressure conditions at the auxiliary valve or the fluid operated device F operated by the auxiliary valve. Flow regulators **19***a* and **19***b* respectively adjust flow from the controlled outlet ports **30***b* and **30***c* of the auxiliary valve to adjust the rate of movement of the fluid operated device F in relatively opposite directions.

In the modified embodiment of FIG. **8**, one of the pilot valve spools is not normally biased to its first position so that the oscillator will not begin a sustained cycle of oscillations until pressure is applied to the actuator **111** to bias the pilot valve **72** to its first position. Thereafter, the sustained cycle of oscillations will continue as above described so long as the actuator **111** remains depressed to compress the biasing spring **73***d*.

The pneumatic timer apparatus including the five-way pressure operated main valve **11** and the three-way pressure operated pilot valves **12** and **13** can be advantageously used to directly control operation of a fluid operated device such as a reciprocating fluid operator F, in applications where it is not desired to either apply an independently adjustable pressure to the fluid operated device or to independently adjust the frequency of the fluid operated device. In such applications, the accumulators **17***a* and **17***b* could be omitted and the main controlled ports **60***b* and **60***c* connected directly to a fluid operated device instead of to the auxiliary valve **10**.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A pneumatic oscillator apparatus for reversibly applying fluid pressure to a fluid operated device comprising an auxiliary flow reversing valve means including an auxiliary valve spool operable to reversibly apply and exhaust fluid pressure to a reciprocable pressure operated device, means defining first and second auxiliary pressure chambers at opposite ends of the spool for operating the same, a main flow reversing valve having first and second main controlled ports respectively communicating with said first and second auxiliary pressure chambers and a main valve spool operable to reversibly apply and exhaust fluid pressure to said first and second main controlled ports, means defining first and second main pressure chambers at opposite ends of said main valve spool, a first pilot valve means having a first controlled pilot port communicating with said first main pressure chamber and a first pilot valve spool operable to reversibly apply and exhaust fluid pressure from said first controlled pilot port when the first pilot spool is respectively in a first and a second position thereof, a first pilot biasing means yieldably urging said first pilot spool to said first position thereof, and means defining a first pilot pressure chamber at one end of the first pilot spool for moving the first pilot spool to said second position thereof in response to a predetermined pressure condition in said first pilot pressure chamber, a second pilot valve means having a second controlled pilot port communicating with said second main pressure chamber and a second pilot valve spool operable to reversibly apply and exhaust fluid pressure from said second controlled pilot port when said second pilot spool is respectively in a first and a second position thereof, a second pilot biasing means yieldably urging said second pilot spool to said first position thereof, means defining a second pilot pressure chamber at one end of the second pilot spool for moving the second pilot spool to said second position thereof in response to a predetermined pressure condition in said second pilot pressure chamber, first and second pilot control passage means respectively communicating the first and second main controlled ports with said first and second pilot pressure chambers, and adjustable orifice means operable to regulate exhaust of fluid from said first and second main controlled ports when said main valve spool is respectively positioned to exhaust fluid from said first and second main controlled ports.

2. An apparatus according to claim **1** including a third adjustable orifice means operable when said aux-

iliary valve spool is positioned to exhaust fluid from said first auxiliary controlled port to regulate exhaust of fluid from said first auxiliary controlled port, and a fourth adjustable orifice means operable when said auxiliary valve spool is positioned to exhaust fluid from said second auxiliary controlled port to regulate exhaust of fluid from said second auxiliary controlled port.

3. An apparatus according to claim 1 including first and second accumulator chambers respectively communicating with said first and second main controlled ports.

4. An apparatus according to claim 1 including a first pressure regulator means for controlling fluid pressure supplied to said main and pilot valve means, and a second adjustable pressure regulator means for controlling fluid pressure supplied to said auxiliary valve means.

5. A pneumatic oscillator apparatus for reversibly applying fluid pressure to a fluid operated device comprising: an auxiliary five-way valve including body means having an auxiliary valve bore and means defining first and second auxiliary pressure chambers at opposite ends of said auxiliary valve bore, said auxiliary valve bore having an auxiliary inlet port, first and second auxiliary controlled ports and first and second auxiliary discharge ports,

an auxiliary spool valve slidable in said auxiliary valve bore and having first and second auxiliary valve pressure faces at opposite ends respectively communicating with said first and second auxiliary valve chambers, said auxiliary valve member having first and second auxiliary valve passage means, said first auxiliary valve passage being operable to communicate said first auxiliary controlled port alternately with said first auxiliary discharge port and said auxiliary inlet port when the auxiliary spool valve is respectively in a first and a second position thereof, said second auxiliary valve passage means being operable to communicate said second auxiliary controlled port alternately with said auxiliary inlet port and said second auxiliary discharge port when said auxiliary spool valve is respectively in said first and said second positions thereof, and first and second auxiliary valve outlet passage means for communicating said first and second auxiliary controlled ports to a fluid operated device,

a main five-way valve means including body means having a main valve bore and means defining first and second main pressure chambers at opposite ends of said main valve bore, said main valve bore having a main inlet port intermediate its ends, first and second main controlled ports, and first and second main discharge ports,

a main valve spool slidable in said main valve bore and having first and second main valve passage means, said first main valve passage means being operable to communicate said first main controlled port alternately with said first main discharge port and said main inlet port when said main valve spool is respectively in a first and a second position thereof, said second main valve passage means being operable to communicate said second main controlled port alternately with said main inlet port and said second main discharge port when said five-day valve is in said first and second positions thereof, said main valve spool having first and second motive pressure faces respectively communicating with said first and second main pressure chambers,

first and second three-way pilot valve means including body means having first and second pilot valve bores therein, said first and second pilot valve bores each having a pilot inlet ports, a pilot controlled port and a pilot discharge port,

first and second pilot valve spools independently slidable in said first and second pilot valve bores respectively having first and second pilot valve passage means, said first and second pilot valve passage means being operable to communicate the respective pilot controlled port alternately with the associated pilot inlet port and the associated pilot discharge port when the pilot valve spools are respectively in a first and a second position thereof,

first and second pilot biasing means respectively urging the first and second pilot spools to said first position thereof,

said first and second pilot bores respectively having first and second pilot pressure chambers therein, said first and second pilot spools respectively having first and second pilot pressures faces respectively communicating with said first and second pilot pressure chambers for moving said pilot spools from said first to said second positions thereof in response to pressure conditions in the respective pilot chamber,

first and second main valve control passage means respectively communicating said first and second pilot controlled ports to said first and second main pressure chambers,

first and second pilot valve control passage means respectively communicating said first and second main controlled ports with said first and second pilot pressure chambers,

means for supplying fluid under pressure to said main inlet port and to said first and second pilot inlet ports, and first and second main discharge passage means for connecting said first and second main control ports to said first and second auxiliary pressure chambers, and first and second adjustable orifice means for respectively regulating flow of fluid from said first and second main discharge ports.

6. An apparatus according to claim 5 including a first, regulator means for controlling the fluid pressure to said main inlet and said first and second pilot inlet ports and a second adjustable pressure regulator means for controlling the fluid pressure applied to the auxiliary inlet port.

7. An apparatus according to claim 6 including third and fourth adjustable orifice means for respectively regulating flow of fluid from said first and second auxiliary discharge ports.

8. An apparatus according to claim 7 including first and second accumulator chambers respectively communicating with said first and second main discharge ports.

9. An apparatus according to claim 5 wherein said first pilot biasing means includes selectively operable means movable between an inoperative position relieving biasing pressure on said first pilot spool and an operative position applying biasing pressure to said first pilot valve spool.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,710,815 Dated January 16, 1973

Inventor(s) Carl H. Morris and Henry N. Oliver

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, line 2, "five-day" should be -- five-way --;

Column 10, line 10, "a" (first occurrence) should be deleted;

Column 10, line 30, "pressures" should be -- pressure --;

Column 10, line 55, the comma (,) after "first" should be deleted.

Signed and sealed this 29th day of May 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents