# United States Patent

**Ruidisch**

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## [54] LOW DIFFERENTIAL PRESSURE GAS FLOW SYSTEM


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[52] **U.S. Cl.**.....**417/404**, 91/303

[51] **Int. Cl.**.....**F04b 17/00**, F04b 35/00, F01l 25/02

[58] **Field of Search**.....417/317, 403, 404, 515, 516, 417/517, 518, 900; 91/265, 275, 303



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[57] **ABSTRACT**

A low differential pressure, gas flow system particularly for laboratory uses. It has a cylinder and piston connected at the ends of the cylinder to give double acting pumping of a gas for circulation to and from a reactor at accurate and surge-free rates. The piston is driven by a power cylinder and piston and there are valves actuated in synchronism with the power strokes to switch the end connections of the cylinder for the gas pumping action, without pressure surges.


**3 Claims, 3 Drawing Figures**

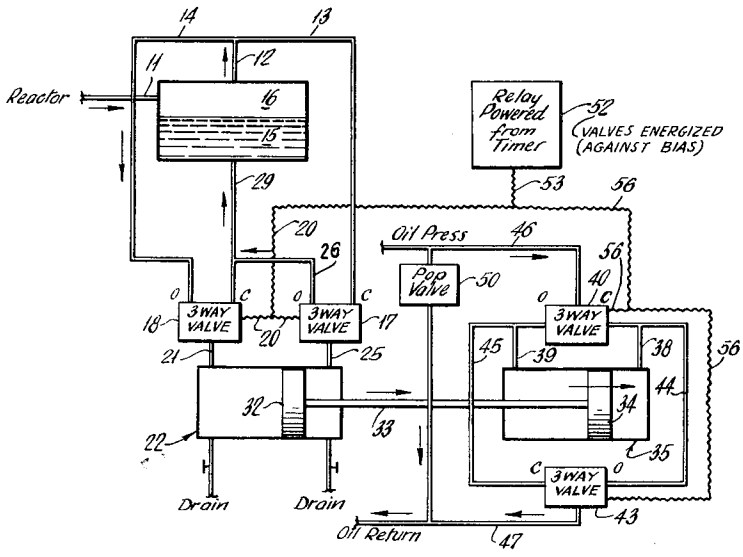


Fig. 1.

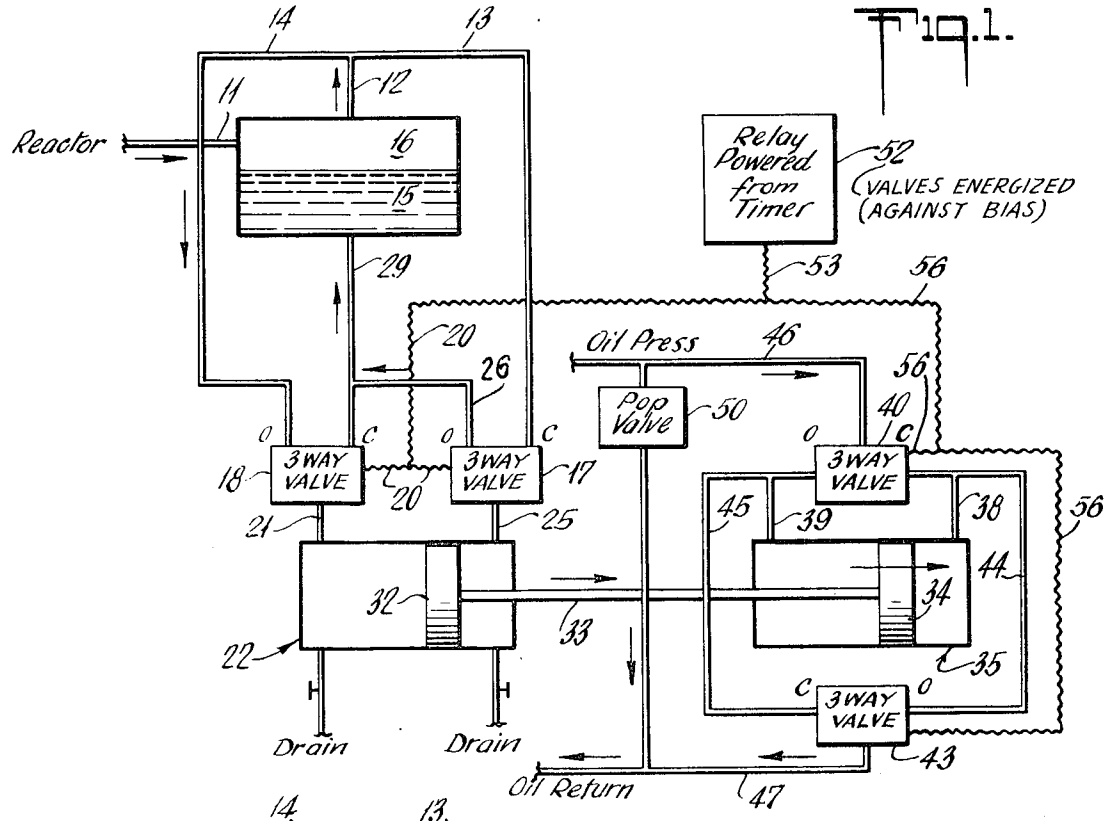

Reactor
Relay Powered from Timer
52
(VALVES ENERGIZED (AGAINST BIAS)
Oil Press
Pop Valve
50
3 WAY VALVE
Drain
Drain
Oil Return
47
43

Fig. 2.

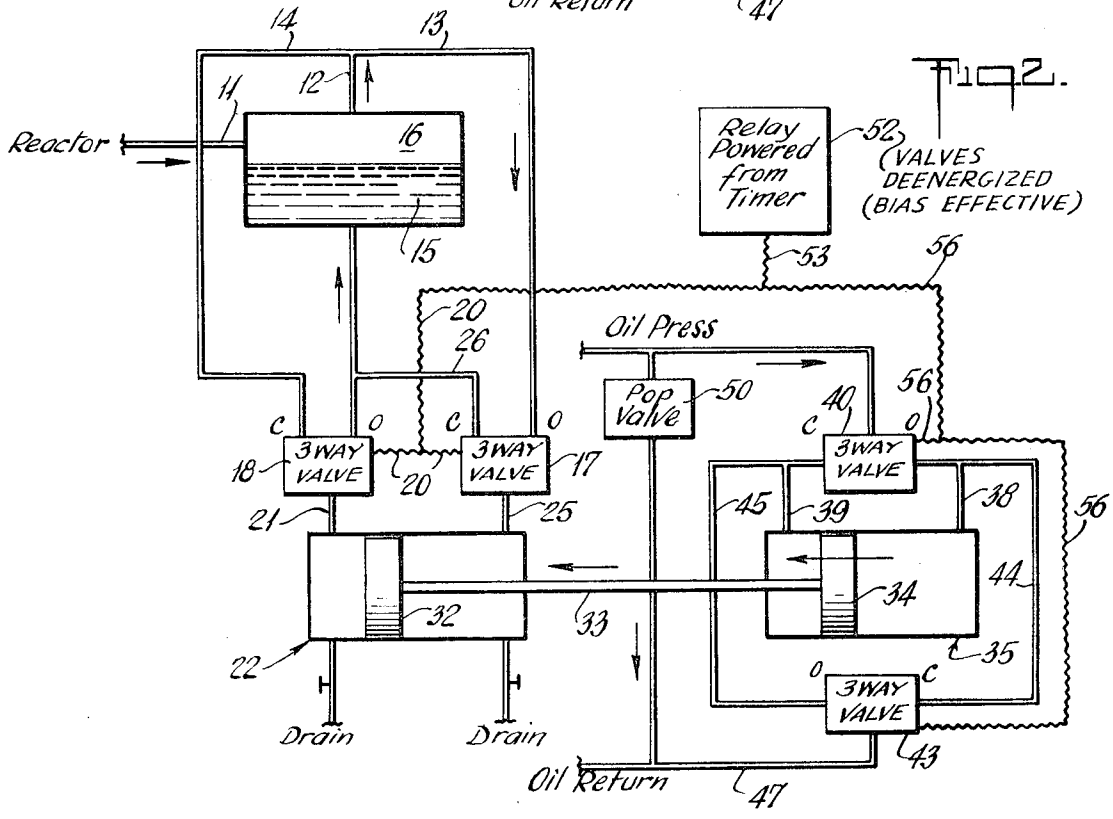
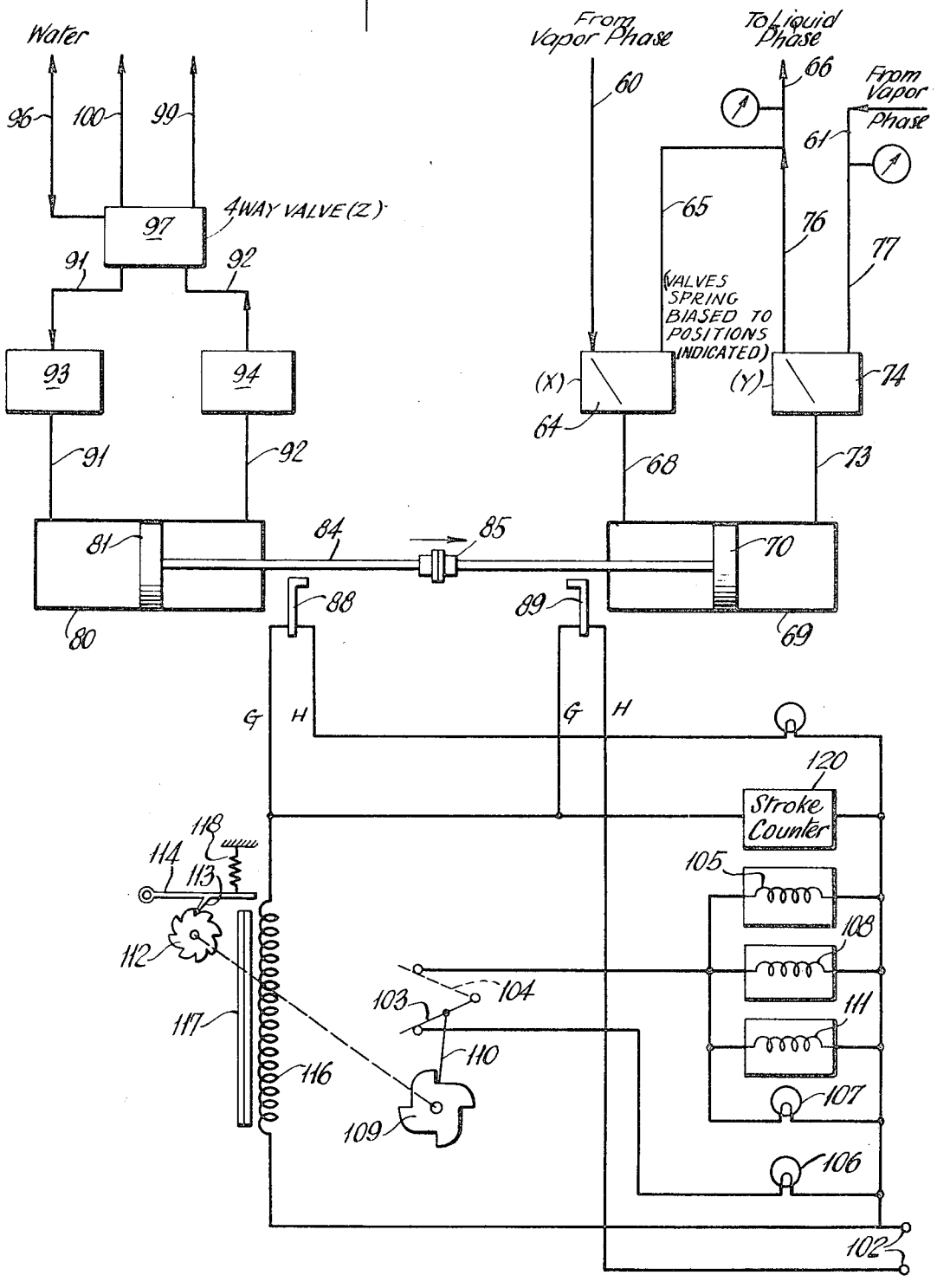

Reactor
Relay Powered from Timer
52
(VALVES DEENERGIZED (BIAS EFFECTIVE)
Oil Press
Pop Valve
50
3 WAY VALVE
Drain
Drain
Oil Return
47
43

Fig. 3.


Water
From Vapor Phase
To Liquid Phase
From Vapor Phase
4 WAY VALVE (Z)
VALVES SPRING BIASED TO POSITIONS INDICATED
(X)
(Y)
Stroke Counter
96
100
99
97
91
92
93
94
60
66
61
65
76
77
74
64
68
73
81
84
85
70
80
88
89
69
G
H
G
H
120
118
114
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116
109
103
104
110
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108
111
107
106
102

# LOW DIFFERENTIAL PRESSURE GAS FLOW SYSTEM

## BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention concerns a low flow gas pumping system. More particularly it relates to a low flow system that is especially applicable to a laboratory process, such laboratory process may be one that employs a reactor and provides for recirculation of an effluent gas from the reactor.

Description of the Prior Art

In connection with laboratory processes and particularly those in the petroleum field, there has been found to be a need for facilities to circulate a gas in small quantities at relatively low yet highly accurate flow rates. However, no known equipment is available that will carry out such pumping at accurate and steady rates of flow for laboratory calculations. Known devices make use of check valves and tend to be inaccurate or unreliable at the low gas flow conditions desired. Consequently, it is an object of this invention to provide a system that will pump a gas stream in recycle, smoothly and accurately without any substantial surge or bounce effects.

## SUMMARY OF THE INVENTION

Briefly, the invention relates to a laboratory process having a reactor and wherein an effluent gas is recycled back to said reactor. In such a process the invention concerns a low differential pressure gas flow system that comprises in combination a work cylinder and piston for moving said gas, and gas flow lines connected from the ends of said cylinder to the input and the outlet from said reactor. The system also comprises externally actuated valve means for switching the flow line connections from said cylinder ends between said input and output, and means for reciprocating said work piston at a predetermined rate. The said last named means comprises a power cylinder and piston, and means for supplying a power fluid under pressure to said power cylinder for actuating said power piston. The foregoing last named means also comprises means for connecting said power piston to said work piston, and power fluid flow lines connected from said power fluid supply means to the ends of said power cylinder. The said last named means also comprises second valve means for switching said power fluid flow lines between the ends of said power cylinder, and means for synchronizing actuation of said externally actuated and second valve means.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and benefits of the invention will be more fully set forth below in connection with the best mode contemplated by the inventor of carrying out the invention, and in connection with which there are illustrations provided in the drawings, wherein:

FIG. 1 is a schematic diagram illustrating a system according to the invention, with the control elements positioned for causing movement from left to right;

FIG. 2 is a schematic diagram like FIG. 1 but illustrates the control elements positioned for causing movement from right to left; and

FIG. 3 is a schematic diagram of another embodiment according to the invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIGS. 1 and 2, it is pointed out that these figures illustrate schematically a system according to the invention which provides for smooth and accurate low volume gas flow. This is particularly useful in a laboratory process where small amounts of gas are transported at low flow rates without surge or bounce.

FIGS. 1 and 2 are substantially identical except that the locations of movable elements are reversed, and they illustrate opposite conditions of pumping action. The same reference numbers are used for the corresponding elements in both figures.



The system may be described with reference to FIG. 1 where there is indicated a reactor **11** that has therein a product that is both in a liquid phase **15** and a gas phase **16**, as indicated by the captions. The process involves recirculation of a gas effluent from the upper portion **16** of the reactor **11** back to the lower or liquid phase part **15**. It is desired to regulate this recirculation gas flow very accurately, both as to rate and total quantity of flow.

The foregoing is accomplished by pumping the gas at a low flow rate out through a gas flow line **12** and then alternately through connecting flow lines **13** and **14** to each of a pair of three-way valves **17** and **18** respectively.

The valves **17** and **18** are conventional and form no part, per se, of the invention. They may be electrically actuated as indicated by the electrical circuit lines **20** that are schematically illustrated.

The gas flow goes from flow line **12** through the line **14**, in the FIG. **1** illustration. It continues through the open path (indicated by the "O") of the three-way valve **18**. Then it goes on to the left-hand end of a work cylinder **22** via a short flow line **21**.

At the other end of the work cylinder **22** there is a gas flow line connection **25** that leads to a common inlet of the three-way valve **17**. When it is in the indicated state, the flow is directed out through another flow line **26** (as indicated by the "O" in FIG. **1**) that connects to a common or return flow line **29**. Line **29** goes back to the reactor **11** and connects into the liquid phase **15** therein.

In work cylinder **22** there is a piston **32** that is reciprocated back and forth within the cylinder by means of a piston rod **33** that is also connected to a similar piston **34** located in a power cylinder **35**.

Power cylinder **35** has hydraulic fluid flow lines **38** and **39** connected to the ends of the cylinder **35**. There is a three-way valve **40** that has its alternatively open or closed outlet ports connected to the flow lines **38** and **39**, as illustrated. There is another three-way valve **43** that has its alternatively open or closed outlet ports also connected to the flow lines **38** and **39**, via lines **44** and **45** respectively.

Hydraulic fluid pressure is applied in a conventional manner to one side or the other of the piston **34** for causing reciprocating movement thereof. The hydraulic pressure may be supplied from any feasible source (not shown) and the hydraulic fluid will be circulated from a pressure line **46** to the inlet port of three-way valve **40**. Then it is circulated to one end or the other of the power cylinder **35**. From the other end of the cylinder, fluid flows out to a return line **47** via the three-way valve **43**. Also, there may be a safety valve **50** (captioned "Pop Valve") that is connected between the pressure line **46** and the return line **47** to bypass the power cylinder in case of overload.

It will be noted that the schematically indicated electrical circuit lines **20** are connected to an electrical control element **52** via a short electrical connection **53**. This control element **52** might take various forms among which is that indicated by the schematic illustration of a box that is captioned "Relay Powered From Timer." It provides electrical energization to actuate the valves **17** and **18** and also by means of additional electrical circuit lines **56**, it actuates the three-way valves **40** and **43**. In this manner the actuation of the valves which control flow of the gas to and from the work cylinder **22** are synchronized with the actuation of valves **40** and **43** that determine the flow of hydraulic fluid to the power cylinder **35**. It may be noted that the three-way valves are all biased to one position when deenergized. Then when energized they are actuated to the other position.

## OPERATION OF FIGS. 1 and 2

The operation will be clear by referring to both FIGS. **1** and **2** where the various elements are in the opposite of two states that exist as the pistons move from left to right (FIG. **1**) and from right to left (FIG. **2**) respectively. By having a timer (not

shown) actuate the relay or control element 52 at predetermined intervals, the rate of pumping of the recirculation gas is determined.

The action may be followed beginning with reference to FIG. 1. Assuming that the valves 17, 18, 40 and 43 are in the indicated state when energized, then the pumping flow of recirculation gas may be traced as follows. Out from the top of the reactor 11, gas will flow through line 12 and line 14 to the open port of valve 18. Then it will flow through the valve 18 and line 21 to the end of the work cylinder 22.

At the same time gas will be pushed out from the other end of cylinder 22 through the line 25 to the common port of the valve 17. From there it will flow out of valve 17's open port (marked "O") and through line 26 to line 29 through which it is returned to the bottom of the reactor 11 into the liquid phase of the product therein.

Simultaneously with the foregoing pumping action, the power for moving the work piston 32 is applied by force from the power piston 34 over the common piston rod 33. It will be clear that in this case the hydraulic fluid (e.g., oil) under pressure will flow as indicated through the valves 40 and 43, to and from the power cylinder 35 for causing movement of the piston 34 from left to right.

It will be understood that the captions "O" and "C" adjacent to the valves 17, 18, 40 and 43 indicate the state of the ports indicated as being open or closed respectively.

FIG. 2 illustrates conditions when the valves 17, 18, 40 and 43 are deenergized. It will be observed that pumping flow is still the same recirculation, but the gas now flows through the valve 17 to the right hand end of the work cylinder 22. Then it returns from the other end of the cylinder through the valve 18 back to the bottom of the reactor. Of course the power cylinder flow connections have been reversed also to cause the opposite force on the piston rod 33.

It is pointed out that by means of the foregoing arrangement there is provided a system which has the advantage of not producing any surge or bounce effects during the flow of gas that is being recycled out from, and back to the reactor. This is accomplished by having the externally controlled three-way valves that switch flow from one side to the other of the piston 32 at the desired point in the reciprocation of the piston, without being dependent upon a change in the direction of flow of the gas. Additionally, the arrangement makes possible the totalizing of gas flow by merely counting the strokes of the piston 32 since the effective displacement within the cylinder 22 will be known. While no such counting is illustrated or indicated in FIGS. 1 and 2, it will be clear that such could be provided in any feasible manner.

The drains that are shown in FIGS. 1 and 2 (connected to work cylinder 22) may be provided, if desired. These would be used to remove any undesired condensate from the work cylinder.

## FIGURE 3 MODIFICATION

In FIG. 3 there is shown a schematic diagram which illustrates the same basic system as that described above with reference to FIGS. 1 and 2. However, in this case the electrical control circuit is illustrated in more detail, and the power system is one that is designed for using water pressure with the outlet flow going to a drain or the like.

In this modification there is shown a gas flow pipe 60 that has a caption "From Vapor Phase". It is connected from a reactor (not shown) or other source of the gas that is to be circulated at low but steady rates. While there is another pipe 61 with the same caption "From Vapor Phase", it may be joined together with the pipe 60 and both go to the same output flow of recycle gas. The pipe 60 is connected to one of the alternatively connected ports of a three-way valve 64. It has the other alternative port connected to a gas flow pipe 65 which leads to a common return flow pipe 66. Pipe 66 is connected to the liquid phase of the reactor, as indicated by the caption "To Liquid Phase".

The three-way valve 64 has a common port that is connected to a flow pipe 68 which leads to one end of a work cylinder 69 that has a piston 70 therein. At the other end of the cylinder 69 there is another flow pipe 73 that leads to the common port of another three-way valve 74. Valve 74 has two alternative ports which lead to one or the other of gas flow pipes 76 and 77. The latter pipes, in turn, are connected to the common return flow pipe 66, and to the pipe 61 respectively.

The power part of the fluid system includes a power cylinder 80 which has a piston 81 therein. There is a common piston rod 84 that interconnects the piston 70 with the piston 81. A flange 85 is attached centrally to the piston rod 84. The flange may take any feasible form. It acts to contact one or the other of a pair of limit switches 88 and 89 that are located near the ends of its path of travel.

The power cylinder-and-piston 80 and 81 is activated by hydraulic fluid flow, i.e., water, that flows through pipes 91 and 92. The pipes are connected to the ends of the cylinder 80. The rate of reciprocating movement of piston 81 may be controlled by a pair of valves 93 and 94 that are connected in each of the pipes 91 and 92 respectively.

The water is supplied under normal pressure, e.g., 100 pounds per square inch, and it is introduced through a pipe 96 which is connected to an inlet port of a four-way valve 97. Valve 97 has additional ports for connecting the water flow from the pipe 96 alternatively to the pipe 91 or to the pipe 92. At the same time, when one of these pipes is connected to the water supply pipe 96, the other will be connected to a discharge pipe 99 or another discharge pipe 100 for allowing the water to flow out to a drain. Thus, the water under pressure will cause reciprocating movement of the piston 81 at a predetermined rate as determined by valves 93 and 94 and this will drive the piston 70 for causing flow of the gas in the recirculation system with the desired smoothness and accuracy at low flow.

The foregoing pumping action is controlled electrically in the system illustrated, although it will be understood that comparable pneumatic controls could be employed. In the illustrated system there is a pair of electric power terminals 102 to which the electrical circuits are connected.

There is a ratchet actuated two-position switch 103 that is successively positioned in the lower position, as illustrated in solid line, or the upper position as indicated by a dashed line 104. This will energize alternatively a pilot light 106, or a group of solenoids 105, 108, 111 and an additional pilot light 107. The latter four are connected in parallel.

The three solenoids are those that actuate the valves that are indicated by the captions. Thus, solenoid 105 (X) actuates the three-way valve 64. Solenoid 108 (Y) actuates the three-way valve 74, and the solenoid 111 (Z) actuates the four-way valve 97. These valves have conventional structure and are spring biased to the indicated positions when the solenoids 105, 108 and 111 are deenergized.

It will be appreciated that the various elements of the system are conventional and form no part, per se, of the invention. However, to assist in the understanding of the operation of the system it will be observed that the ratchet actuated, two-position switch 103 is constructed with a four-lobe cam 109 that cooperates with a cam follower 110 which is operatively connected to the switch blade 103. Cam 109 is directly driven by an eight-tooth ratchet wheel 112 that has a pawl 113 attached to a pivoted arm 114 for ratcheting the wheel 112 around one step at a time whenever the arm 114 is actuated. Thus, the switch 103 includes a solenoid 116 that will energize a magnetic core 117 when current flows through the solenoid. The magnetic field, in turn, attracts the arm 114 and pulls it down against the upward force of a spring 118. The completion of that action turns the ratchet wheel 112 one eight of a revolution.

It will be observed that the ratchet action, just described, alternately causes the cam follower 110 to rest on a valley or on a lobe of the cam 109. Consequently, the switch 103 successively changes position between the full line and dashed line location, as noted above.

Energization of the solenoid **116** takes place at the ends of the reciprocation of the pistons and is controlled by the limit switches **88** and **89**. It will be clear that at the end of each stroke when the flange **85** contacts one of the limit switches, it will cause that switch to close and thus energize the solenoid **116**. It will remain energized only until the piston rod **84** (which carries the flange **85**) reverses and moves away so as to release the limit switch.

It is pointed out that there is a stroke counter **120** which is electrically connected in parallel with the solenoid **116**. Consequently, each time a stroke in either direction is completed there will be a count registered. This is done by energization of the counter **120** simultaneously with the limit switch closings.

From the foregoing it will be clear that the system will continue to cause desired pumping action of the low flow gas so long as electrical controls are energized and the water power is applied for moving the power piston **81**.

## OPERATION OF FIGURE 3

The operation of FIG. **3** may be briefly traced as follows. Assuming that electric power is applied to the terminals **102**, and the valves **93** and **94** are set to produce a desired rate of drive for moving the pistons **70** and **81**, the movement will be in the direction of the arrow when the switch **103** is, as illustrated, with the circuit completed to light the pilot **106**. When the end of that stroke is reached, the flange **85** will contact the limit switch **89** and close it. This energizes the counter **120** and simultaneously ratchets the switch **103** to the other position (indicated by the dashed line **104**).

When the switch **103** takes the other position, it energizes the solenoids **105**, **108** and **111** which cause the three-way and four-way valves to be shifted to the opposite states. Therefore the power piston **81** starts back and simultaneously the pumping action of the work piston **70** is reversed from one side to the other. This continues until the other limit switch **88** is contacted by the collar **85**.

Closing of the limit switch **88** again energizes the stroke counter **120** and the ratchet solenoid **116**. The latter causes the switch **103** to be returned to the first position so that the solenoids **105**, **108** and **111** are deenergized and the valves **64**, **74** and **97** go back to the first state, which again causes movement from left to right of the pistons **81** and **70**.

It may be noted that the limit switches **88** and **89** only close temporarily when contacted by the collar **85**. They open again when the collar moves away. Consequently the energization of the relay solenoid **116** and the counter **120** is only of short duration each time.

While the foregoing embodiments of the invention have been described above in considerable detail in accordance with the applicable statutes, this is not to be taken as in any way limiting the invention but merely as being descriptive thereof.

I claim:

**1.** In a laboratory process having a reactor and wherein an effluent gas is recycled back to said reactor, a low differential gas flow system comprising in combination

a work cylinder and piston for moving said gas,

gas flow lines connected from the ends of said cylinder to the input and the output from said reactor comprising alternate connections from each said cylinder ends to said reactor input and to said reactor output respectively,

externally actuated three-way valve means for switching the flow line connections from said cylinder ends between said input and output, and

means for reciprocating said work piston at a predetermined rate,

said last named means comprising a power cylinder and piston,

means for supplying a power fluid under pressure to said power cylinder for actuating said power piston,

means for connecting said power piston to said work piston,

power fluid flow lines connected from said power fluid supply means to the ends of said power cylinder,

second valve means for switching said power fluid flow lines between the ends of said power cylinder, and

means for synchronizing actuation of said externally actuated and second valve means.

**2.** The invention according to claim **1** wherein said externally actuated valve means comprises a pair of three-way valves.

**3.** The invention according to claim **2** wherein said three-way valve means are biased to one position when deenergized and actuated to the other position when energized.

* * * * *