Oct. 24, 1961 W. A. SWANEY 3,005,417

PNEUMATIC SYSTEM FOR PUMPING LIQUID

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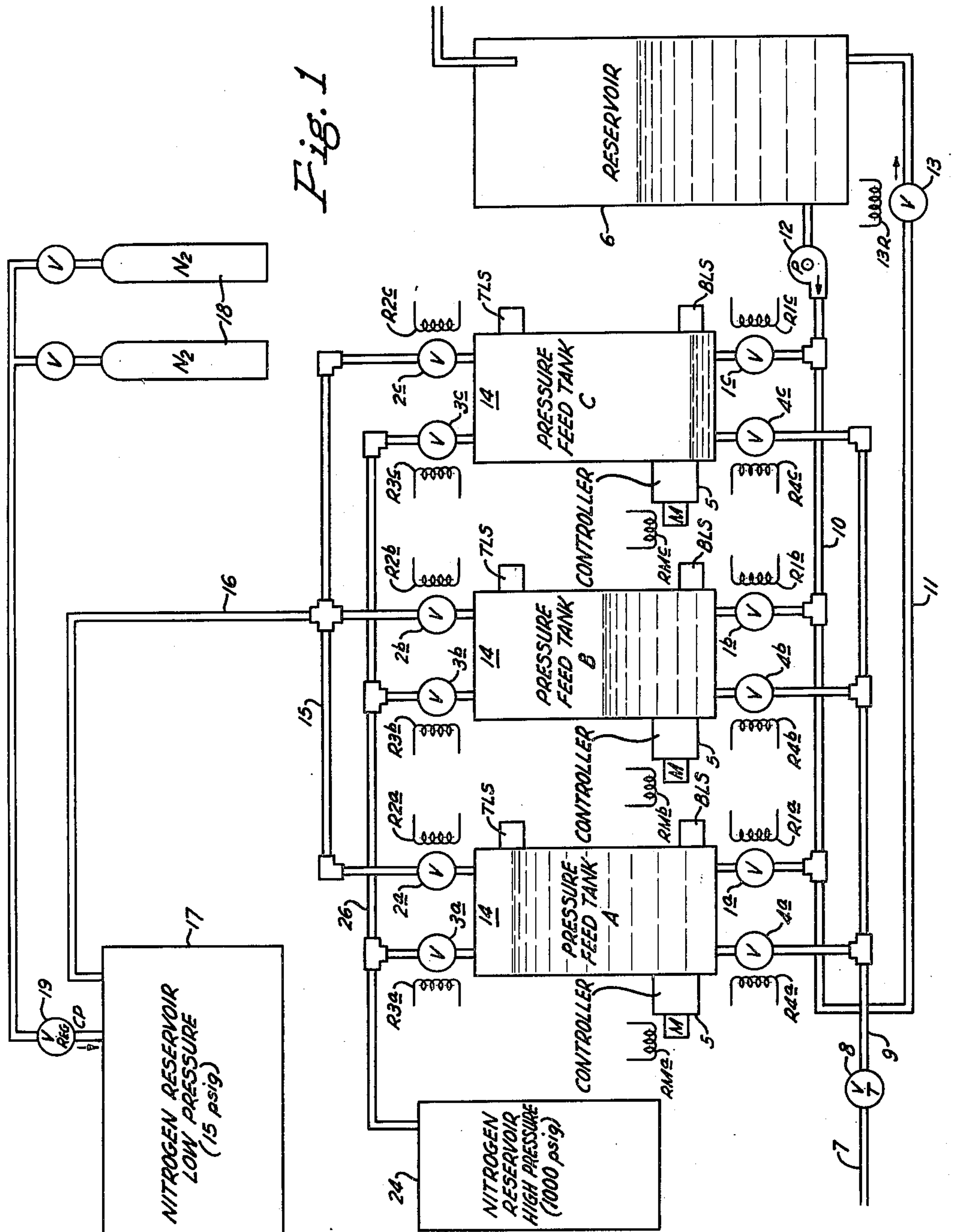
Fig. 1



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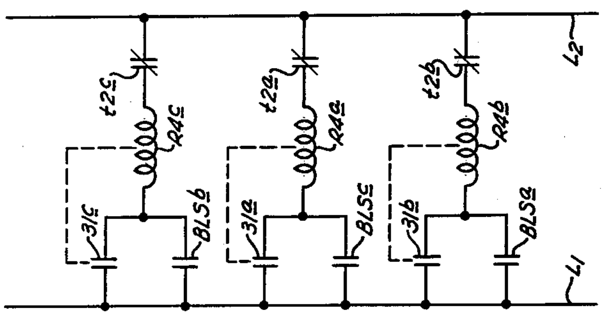

Fig. 2

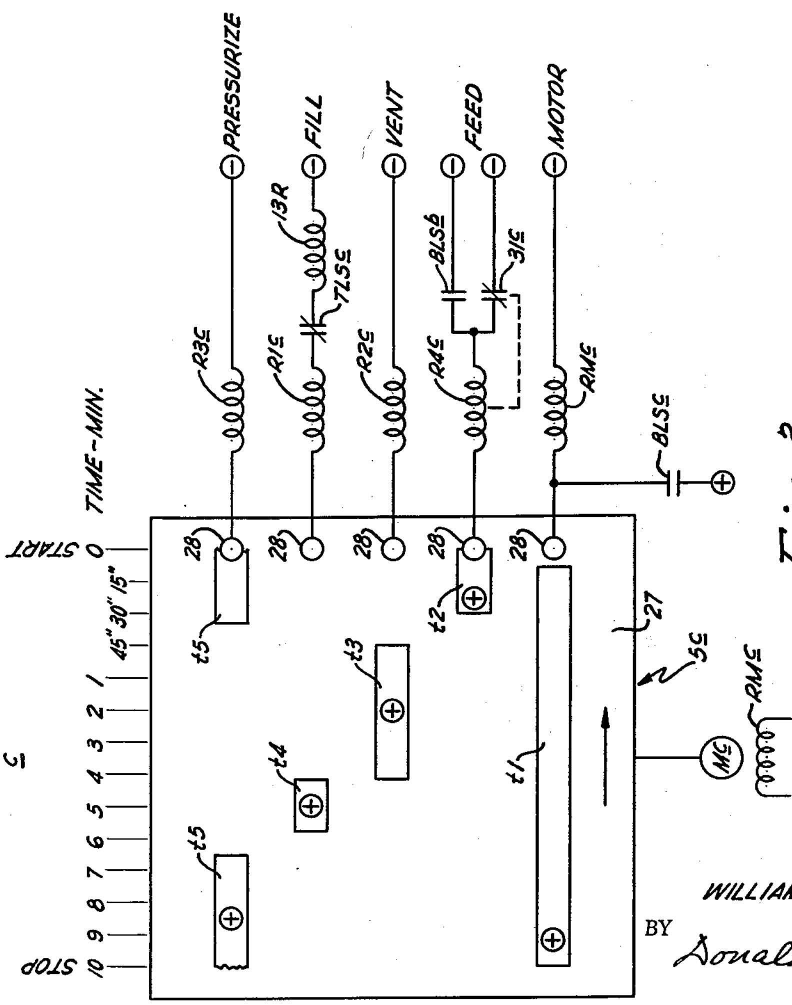

Fig. 3

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PNEUMATIC SYSTEM FOR PUMPING LIQUID

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This invention relates, as indicated, to a pneumatic system for pumping liquid and, more particularly, to a system for pumping corrosive and abrasive materials at relatively high temperatures and pressures.

In many chemical processing operations requiring the transfer of liquid from one location to another, the liquid to be handled will often have such abrasive and corrosive properties that it is not adapted for handling by gear pumps or other forms of conventional pumping equipment. In addition its characteristics may be such that its handling by such equipment will result in uncontrollable pressure pulses and deviations in rate of flow of a nature which may make control of temperature or other processing factors extremely difficult. As an example of one highly abrasive and viscous liquid for which the pumping system of this invention is particularly adapted, mention may be made of pitch produced as the residue of a coal-tar distillation procedure.

One of the principal objects of this invention is, accordingly, to provide a system which is especially adapted for pumping highly abrasive and viscous liquids at high pressures without pulsation or variation in the rate of flow. A further and related object is to provide a pumping system of this character in which a gas under pressure is used to pneumatically pressurize liquid and force it from one location to another. A still further object is to provide a system in which an inert gas such as nitrogen is utilized as the pneumatic pressurizing medium.

To the accomplishment of the above and other ends, the pumping system of this invention, according to a preferred embodiment, is comprised of at least two, preferably three, feed tanks which are filled with the liquid to be handled and then pneumatically pressurized to pump it through a delivery conduit. In a manner to be described, each of the feed tanks is provided with an identical arrangement of valves for effecting the liquid filling and feeding operations thereof. In addition each of the tanks is provided with upper and lower limit switches, which are responsive to the level of fluid in the feed tanks, and a motor driven controller operated in a timed manner for actuating the feed tank valves to effect a sequential discharge or feeding operation thereof. More specifically the valve control mechanism, which includes the level responsive limit switches and the controller, operates in such manner that emptying of one of the feed tanks initiates discharge of fluid from a succeeding tank, with the valve control mechanism thereafter operating to fill the tank which has emptied with fluid and to pneumatically pressurize such fluid therein as an incident to its being conditioned for a subsequent cyclical and sequential feeding or pumping operation.

Other objects and advantages of the invention will become apparent from the following description and the accompanying drawings, in which:

FIGURE 1 is a diagrammatic showing of a preferred embodiment of a pneumatic system for pumping liquid in accordance with the principles of this invention;

FIGURE 2 shows an interlocking control circuit for effecting sequential operation of the pressure tank feed valves of the system shown in FIGURE 1; and

FIGURE 3 is a diagrammatic and developed showing of one of the timed controllers associated with each of the pressure feed tanks in the system of FIGURE 1 which illustrates somewhat graphically the manner in which it provides a timed and sequential energization of the control circuits for the filling and feeding valves.

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As shown in FIGURE 1 of the drawings, the preferred embodiment of the pneumatic pumping system of this invention is comprised of three pressure feed tanks A, B and C. In a manner to be described, these tanks, after being filled with liquid to be pumped, are pneumatically pressurized to force the liquid therein under pressure through a delivery conduit. The feed tanks are sequentially operated and connected with the delivery conduit in such manner that it is always connected with and receiving fluid from at least one tank while the remaining tanks are being filled and conditioned for a subsequent liquid feeding operation. Although this can be accomplished by a system having only two pressure feed tanks, the use of three feed tanks is preferred since this number reduces the size of the tanks and thereby the cost of the apparatus for a given pumping capacity, facilitates the intermediate operations of filling and pressurizing the tanks, and provides a smoother transition of the liquid feeding operation from one tank to another.

Each of the tanks A, B and C has identical apparatus for controlling its liquid filling and feeding operations and, in the following description, identical elements therein have been given similar designations. Each tank control apparatus includes four valves, a fill valve **1**, a vent valve **2**, a pressurizing valve **3**, and a feed valve **4**, which are normally closed and are actuated to open position in response to energization of control windings R. Energization of the windings R is under the control of a timed controller **5**, a bottom limit switch BLS, and a top limit switch TLS. The limit switches BLS and TLS are actuated in response to the level of liquid in the tanks with which they are associated and are preferably float actuated. The switches BLS are normally open switches, which are closed in response to the level of the liquid falling to a predetermined level, and the switches TLS are normally closed switches, which are opened in response to the liquid rising to a predetermined level. Each controller **5** is operated by a clock motor M which is started and continues to run upon energization of its control winding R. In the following description and in the drawings, small case letters *a*, *b*, and *c* used as a suffix indicate the pressure tank with which the different control elements are associated and the use of the letter R as a prefix to a numeral indicates the winding controlling the operation of the element designated by such numeral.

The system of this invention is adapted as shown in FIGURE 1, for example, to pump fluid continuously from a reservoir **6** through a delivery conduit **7** which has a throttle valve **8** for regulating the rate of liquid flow. The feed valves **4** when opened upon energization of their respective control windings R provide connections between the feed tanks, A, B and C and a manifold **9** which delivers the fluid through the valve **8** to the delivery conduit **7**. To fill the feed tanks, the fill valves **1** when opened upon energization of their respective control windings R provide connections for the feed tanks with a fluid supply manifold **10**. The manifold **10** is connected with a return conduit **11** and cooperates therewith to provide a fluid circuit through which fluid is circulated from the reservoir **6** by a centrifugal pump **12**. A normally open valve **13** in the return conduit **11** has a control winding **13R** effective upon energization for operating it to its closed position. Energization of the winding **13R** is effected in conjunction with energization of the windings R for the fill valves **1** in a manner to be described such that the valve **13** is closed each time one of the fill valves **1** is opened. Closure of the valve **13** in this manner causes all of the fluid being pumped by the centrifugal pump **12** through the manifold to be diverted through the open fill valve 1 into the feed tank with which it is connected.

A closed pneumatic circuit, preferably using nitrogen as a pressurizing medium, is utilized for pressurizing the spaces 14 at the upper ends of the feed tanks A, B and C incident to liquid feeding and filling operations thereof. This circuit comprises an exhaust manifold 15 which is connected with the spaces 14 by the vent valves 2. A conduit 16 connects the manifold 15 to a low pressure reservoir 17 in which a supply of nitrogen is maintained at a constant pressure. Make-up nitrogen is fed to the reservoir 17 from supply cylinders 18 through a regulating valve 19 which is preferably adjusted to provide a pressure as indicated of about 15 pounds per square inch in the reservoir 17. The reservoir 17 supplies nitrogen to a pump 20 through a conduit 21 which is provided with a check valve 22 for preventing feed back into the reservoir 17. The pump 20 compresses and delivers the nitrogen through a conduit 23 to a high pressure reservoir 24. A regulating valve 25 in the conduit 23 is adjusted to provide a pressure in the reservoir 24 of about 1000 pounds per square inch. The reservoir 24 supplies nitrogen under high pressure to a manifold 26 which is connected through the pressurizing valves 3 with the spaces 14 in the feed tanks A, B and C. A closed pneumatic circuit of this character, using nitrogen gas as a pressurizing medium, is preferred since nitrogen will not adversely affect many liquids to be pumped such as some petroleum and coal-tar derivatives. In the case of liquids which are not adversely affected by air, the reservoir 17 and its connections with the pump 20 and the exhaust manifold 15 may be omitted.

FIGURE 3 shows schematically the circuits for the control windings R of the valves 1–4 and timer motor M at the unit C and the manner in which such circuits are energized by the controllers 5. In this showing the controller *5c* is illustrated diagrammatically as comprising a drum switch 27 which has been unwrapped and shown in plan in the manner of a circular cam development. It has a circumferential length of 360° between the start (0 min.) and stop (10 min.) points indicated on the time scale at the top of this figure and the clock motor upon starting thereof is adapted to rotate it one revolution, or 360°, from its start point to its stop point. The drum switch 27 carries five conductor bars or contacts, designated *t1*–*t5* which have different arcuate lengths and have electrical contacting engagement with stationary contacts 28 as they are rotated relative thereto by the drum 27 for different times and intervals corresponding to their respective locations and arcuate lengths. The arcuate contacts *t1*–*t5* and the circuits connected with the contacts 28 are polarized as indicated and are thus energized when connected for the purposes designated at the right of FIGURE 3. The drum switch 27 is a conventional structure which per se forms no part of this invention and it will be understood that other forms of conventional timer switches, such as disc or cam-operated switches, may be employed for this purpose.

The manner in which the controllers 5 and circuits operated thereby control the filling and pressurizing of the tanks A, B and C will be best understood from an explanation of the operation of the timer *5c* for the condition shown in FIGURE 1. In this showing the level of liquid in the tanks A, B and C indicates that tank A has been filled and pressurized, tank B is being filled, and tank C is being discharged and almost empty. As the level in tank C moves downwardly, float limit switch BLS*c* closes and, referring to FIGURE 3, energizes control winding RM*c* to start clock motor M*c*. Just prior to starting clock motor M*c*, it will be noted that valve *4c* is open by reason of its control winding R*4c* being energized through drum contact *t2*, and the space *14c* is pressurized by reason of control winding R*3c* for pressure valve *3c* being energized through contact *t5*. With both windings R*4c* and R*3c* energized, the contents of tank C will be discharging into the manifold 9 connected to the delivery conduit 7.

After starting motor M*c* by closure of float switch BLS*c*, such switch stays closed until filling of the tank C is initiated to raise the level of liquid therein. Before filling of tank C is started, motor holding contact *t1* will have completed an energizing circuit through coil RM*c* so that subsequent opening of switch BLS*c* will not interrupt the operation of motor M*c* which will continue to operate through the 10 minute cycle indicated. At the end of the 10 minute interval, contact *t1* will disengage from its stationary contact and deenergize coil RM*c* to stop motor M*c* with the drum switch in the position shown in FIGURE 3.

After operation of timer *5c* is initiated as explained above, feed tank C will continue for a period of 30 seconds to discharge liquid through its open discharge valve *4c* into the delivery manifold 9. At the end of this interval, winding R*4c* is deenergized as the result of timer contact *t2* moving out of engagement with the contact 28. Opening of the energizing circuit for the winding R*4c* of course results in valve *4c* reverting to its closed position to disconnect tank C with respect to manifold 9. Momentary deenergization of R*4c* causes holding contact *31c*, which is indicated by the broken line as being operated in response to energization of coil R*4c*, to open so that subsequent engagement of contact *t2* with stationary contact 28 will not reenergize coil R*4c*, until called on to do so by limit switch BLS*b* in a manner to be described. A few seconds later, contact *t5* disengages from contact 28 to deenergize coil R*3c* and thereby close valve *3c* to disconnect tank C from the pressurizing manifold 26.

At the end of an interval of 45" after starting of motor M*c*, contact *t3* operates to energize R*2c* which opens valve *2c* to connect the space *14c* with the low pressure vent manifold 15. This reduces the pressure in the space *14c* and conditions the tank C for filling with fluid upon opening of fill valve *1c* and closure of valve 13 in a manner to be described. With reference to FIGURE 3, it will be noted that the contact *t3* has a length of about 3 minutes and 30 seconds, and this interval is used in the preferred practice of the invention to effect a very slow opening movement of the valve *2c* and thus a gradual venting of the pneumatic pressurizing medium in the space *14c* to the reservoir 17. Gradual venting in this manner may be effected by using a conventional slow acting valve arrangement comprising, for example, an air operated diaphragm valve for connecting the space *14c* to the manifold 15, an expansion chamber for supplying air to the diaphragm valve for affecting its actuation, and a solenoid actuated air valve responsive to energization of the coil R*2c* for bleeding air into the expansion chamber and gradually building up the pressure therein. With a valve arrangement of this character, the opening movement of the diaphragm valve will be proportional to the size of the expansion chamber and the rate at which air pressure builds up therein. A similar slow operating valve arrangement is preferred for use as the pressurizing valves 3.

At about the time contact *t3* operates to deenergize coil R*2c* and close vent valve *2c*, timing contact *t4* operates to energize a circuit which includes coils R*1c* and 13R. These coils in turn open valve *1c* and close valve 13 so that the centrifugal pump 12 is rendered effective to force fluid into tank C. When the tank C has been filled, float limit switch TLS is opened and deenergizes both of fill valve coils *1c* and 13R so that the tank C is disconnected from the manifold 10 and the output of pump 12 is returned to the reservoir 6 through return conduit 10. With reference to the fill circuit for the coil R*1c* in FIGURE 3, it will be understood that the similar circuits for the fill coils operated by the timers *5a* and *5b* include a coil 13R which is energized to close the valve 13 when either of the tanks A or B is to be filled.

After filling of the tank C, the contact t5 energizes coil 3c to connect the space 14c with the pneumatic pressure manifold 26. This pressurizes and conditions the tank C for a subsequent feeding operation.

The final operation of the drum 27 takes place as it returns to the zero or start position shown in FIGURE 3. As it moves through the 10 minute stop position, its contact t1 moves out of engagement with the contact 28 connected to motor operating coil RMc. Motor Mc then stops with the drum 27 in its zero position as shown in FIGURE 3. In this position, contact t2 is connected with the circuit for coil R4c and this circuit will be energized to open feed valve 4c and repeat the emptying and fill cycle of tank C in response to emptying of tank B and closure of limit switch BLSb. As explained above, energization of coil R4c by closure of BLSb is effective to establish a holding circuit through holding contact 31c which closes in response to energization of coil R4c.

From the foregoing, it will be apparent that the bottom limit switches BLS interlock the operation of the tanks by placing a succeeding tank on feed in response to emptying of another tank. This is accomplished by an interlocking energizing circuit of the type shown diagrammatically in FIGURE 2. This figure shows the energizing circuit for each of the feed valve control coils R4. The coil R4c is connected across the line L1—L2 by limit switch BLSb as explained above; the coil R4a by limit switch BLSc; and the coil R4b by the limit switch BLSa. From this, it will be apparent that emptying of tank A places tank B on feed; emptying of tank B places tank C on feed; and emptying of tank C places tank A on feed. Intermediate the times of emptying and being placed on feed, the controller 5 for each tank takes over and effects the filling and pressurizing operations essential to condition it for a subsequent feeding operation as explained above.

Since the valves 1–4 and their control windings and energizing circuits therefor have been shown diagrammatically, it will be appreciated that such showing does not provide safety interlocks for preventing untimely operation of the system components or signal elements for indicating the operating condition of the apparatus. In commercial embodiments of the pumping system of this invention, interlocking safety controls are required to insure opening and closing movements of the valves 1–4 in a predetermined sequence. In addition, signals in the form of lights and audible alarms should be provided to indicate the operating condition of the apparatus and to warn of improper operation resulting, for example, from a sticking valve. The provision and operation of signals and safety controls of this character require the use of control relays in the energizing circuits for the control windings R. Accordingly it will be appreciated that such windings, in commercial embodiments of the invention, will not as a general rule respond directly to the feed tank operations or actuate the valves 1–4 directly as shown diagrammatically in the drawings, but will operate through intermediate relays and control circuits. While modifications for these and similar purposes are contemplated and have been used in the practice of this invention, they do not involve a departure from the essential principles of the invention as disclosed above and shown diagrammatically in the drawings.

While several embodiments of my invention have been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. A pneumatic system for pumping fluid comprising, the combination with a fluid supply conduit, a fluid delivery conduit, and a plurality of liquid feed tanks respectively adapted to be filled with fluid from said supply conduit and to discharge such fluid under pressure into said delivery conduit, of a plurality of separate valve means respectively controlling the filling and discharge operation of said tanks, each of said separate valve means comprising a discharge valve connecting one of said tanks with said delivery conduit, a fill valve connecting said one tank with said supply conduit, and pneumatic valve means for conditioning said one tank for a liquid feeding operation by introducing gas under pressure to pressurize the liquid therein, each of said tanks having a separate motor driven controller operable in a cyclic manner and including a plurality of means respectively effective during each cycle of operation and at sequentially timed intervals for closing its discharge valve and operating its fill valve and its pneumatic valve means to thereby fill it with gas-pressurized liquid, and means providing for successive operation of said tanks comprising a lower limit control in each of said tanks which is actuated in response to the fluid therein falling to a predetermined level and includes means for actuating the motor driven controller for such tank and for opening the discharge valve of a succeeding tank, said motor driven controllers operating respectively at a predetermined timed interval after actuation by said lower limit controls to close said discharge valves.

2. A pumping system as defined in claim 1 characterized by the provision of separate electric drive motors for operating said controllers, means responsive to actuation of each of said lower limit controls for starting one of said electric drive motors, and each of said controllers including means for stopping its said drive motor at the end of each operating cycle thereof.

3. A pumping system as defined in claim 1 characterized by said pneumatic means comprising a vent valve and a gas admission valve in the upper end of each tank, and a closed circuit connecting said gas admission and vent valves comprising a low pressure reservoir for receiving gas discharged from said tanks through said vent valves, a high pressure reservoir for supplying gas under pressure to said admission valves, and means including a compressor for pumping gas from said low pressure reservoir to said high pressure reservoir.

4. A pumping system as defined in claim 1 characterized by the provision of a reservoir for the fluid to be pumped, a continuously operating pump for delivering fluid from said reservoir to said supply conduit, a return conduit connecting said supply conduit with said reservoir, a normally open flow-control valve in said return conduit, and means operated by said controllers for closing said flow-control valve to render said supply conduit operative to deliver fluid through said fill valves to said feed tanks.

5. A pneumatic system for pumping fluid comprising a plurality of liquid feed tanks respectively adapted to be filled with liquid and for the discharge of such liquid under pneumatic pressure, and pneumatic means for pressurizing each of said tanks comprising a vent valve and a gas admission valve in the upper end of each tank, and a closed circuit connecting said gas admission and vent valves comprising a low pressure reservoir for receiving gas discharged from said tanks through said vent valves, a high pressure reservoir for supplying gas under pressure to said admission valves, and means including a compressor for pumping gas from said low pressure reservoir to said high pressure reservoir.

6. A pneumatic system for pumping fluid comprising a plurality of liquid feed tanks, a fluid supply conduit, means including a plurality of normally closed fill valves for connecting said feed tanks with said supply conduit, means for selectively operating said valves to open position, a reservoir for the fluid to be pumped, a continuously operating pump for delivering fluid from said reservoir to said supply conduit, a return conduit connecting said supply conduit with said reservoir, a normally open flow-control valve in said return conduit, and said selective valve operating means including means for closing said flow-control valve in response to operation of any of said fill valves to open position to thereby render

said supply conduit operative to deliver fluid through the open fill valve into one of said tanks.

7. A pneumatic system for pumping fluids comprising, in combination, a fluid supply conduit, a fluid delivery conduit, a plurality of liquid feed tanks arranged between said conduits and respectively adapted to be filled with fluid from said supply conduit and to discharge such fluid under pressure into said delivery conduit, a pair of valves in the bottom of each of said tanks respectively controlling the connections thereof with said supply and delivery conduits, pneumatic means for pressurizing said tanks including a pressurizing valve and a venting valve in the upper end of each of said tanks, a separate motor operated controller for each of said tanks operable in a cyclic manner and including a plurality of means respectively effective during each cycle of operation and at sequentially timed intervals for operating the valves therein, each of said controllers operating sequentially to close the discharge and pressurizing valves of the tank which it controls, to open the said vent and fill valves therein to fill said tank and then close said vent and fill valves, and then open the pressure valve therein to pressurize the fluid therein for a fluid discharge operation, and a separate means in each of said tanks responsive to the fluid therein falling to a predetermined level for actuating its controller and for opening the discharge valve of a successive tank, said controllers operating respectively at a predetermined timed interval after actuation by said last named means to close said discharge valves.

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