A one-shot sensor valve receives a mechanical force from pump rod movement and operates to pressurize a one-shot air tank from a regulated air supply. When the pump rod moves back to its original position, the one-shot tank is discharged into fluidic logic circuitry which energizes a counter and passes the air signal to a ratemeter transfer valve and into a one-shot storage valve. The one-shot storage valve stores air pressure in a second one-shot air tank and a time air tank receives compressed air at a constant and predetermined rate from a flowrater through the ratemeter transfer valve. When the transfer valve is energized, the pressure in the time tank is transferred through a booster relay to a readout device. As the signals are coupled from the counter to the ratemeter, the second one-shot air tank is released into a dump pilot valve operator and a dump valve to discharge the time air tank. In the time between the dumping of the time tank and its transfer into the readout device, the time tank is building pressure at a set rate determined by the flowrater. The time between pulses is then represented by a pressure buildup in the time tank. In an alternative embodiment, the flowrater is replaced with a timing motor which drives a timing disc having a hole therethrough which causes air to be passed alternately through a pair of air switches which respectively cause an air volume tank to be pressured up and dumped at a rate commensurate with the rotation of the disc. Based upon the principal that when a given volume of air at a given pressure is allowed to expand into a second volume on a timed cycle, the resultant pressure at any time is a measure of the time from the first cycle to the time of measurement, the pressure in the air timing tank at any time is thus proportional to the rate of pulses generated by the one-shot sensor valve or by the mechanical force that causes the one-shot sensor valve to operate.

9 Claims, 3 Drawing Figures
FIG. 1

10 REGULATED AIR SUPPLY
12 LOW PRESSURE REGULATOR
13 SIGNAL BLEED VALVE
14 ONE-SHOT TANK
15 PUMP
16 NOR GATE
17 NOR GATE
18 20 21
19
22 23 24
25 26 27
28 29 30
31 32 33
34 35
36 37
38 39 40

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FIG. 2
PNEUMATIC RATEMETER AND COUNTER

BACKGROUND OF THE INVENTION

This invention relates to the measurement of the total number of impulses and the instantaneous rate of such impulses. More specifically, the invention relates to apparatus using fluidic components to count impulses corresponding to pump strokes in oil well equipment and which determine the total number of such impulses and the rate of such impulses.

In the art of drilling oil and gas wells, it is well known to measure the total number of certain reoccurring events, such as the revolutions of a drill pipe, the depth increments of the drill pipe, the number of strokes of a mud pump and the like. It has also been recognized by those in the art that it is desirable to know the instantaneous rate at which such variables occur. For example, U.S. Pat. No. 3,541,852 issued on Nov. 24, 1970, and assigned to the assignee of the present invention, refers to an electronic system for measuring and recording the depth and the rate of penetration of a drill bit. It should be recognized, however, that under certain drilling conditions, it is highly desirable to use a pneumatic system instead of an electrical system in order to lessen the possibility of an explosion at the drill site. By way of further example, there have been systems proposed in the art involving pneumatic counting and rate measuring devices such as is disclosed in U.S. Pat. No. 3,348,231, issued on Oct. 17, 1967. However, such prior art pneumatic systems are quite complex and expensive and have failed to produce the accuracy desired by the industry.

It is therefore the primary object of the present invention to provide a new and improved apparatus for counting the number of impulses corresponding to the movement of a reciprocating oil well apparatus;

It is a further object of the invention to provide a new and improved apparatus for measuring the rate of impulses resulting from the movement of a reciprocating oilfield apparatus;

It is yet another object of the invention to provide a new and improved apparatus which pneumatically monitors with improved accuracy the total number of reoccurring impulses and the instantaneous rate of occurrence of such impulses.

The objects of the present invention are accomplished, generally, by the provision of apparatus which causes air pressure to be stored in a timing tank at a predetermined set rate wherein the pressure in such tank is transferred to a readout device at a time corresponding to the occurrence of another impulse. Thus, the amount of pressure which is transferred to the readout device is proportional to the instantaneous rate of occurrence of such impulses.

These and other objects, features and advantages of the present invention will be more readily understood from a reading of the following detailed specification and drawing, in which:

FIG. 1 is a schematic illustration of the counting circuitry according to the present invention;

FIG. 2 is a schematic illustration of the ratemeter circuitry according to the present invention; and

FIG. 3 is a schematic illustration of an alternative embodiment of a portion of the ratemeter circuitry of FIG. 2.

Referring now to the drawing in more detail, especially to FIG. 1, there is illustrated a regulated air supply 10 having an output air line 11 which is coupled into a low pressure air regulator 12, the output of which is monitored by the air gauge 13. The air line 11 is also connected to an input 14 of a one-shot sensor valve 15. The one-shot sensor valve 15 is a spring loaded two way valve which is connected to the reciprocating pump rod 16 of a pump 17, for example, a mud pump on an oil well derrick (not shown). The one-shot sensor valve is conventional, for example the Microswitch No. 64NF1 available from the Honeywell Corp. of Freeport, Ill. Connected to another input 18 of the sensor valve 15 is an air tank 19 bearing the legend "one shot tank." The sensor valve 15 also has an output orifice 20 to which a long, for example, 200 feet length of pipe or tubing 21 is connected. A conventional bleed valve 22 is connected to the air line 21.

The output of the air gauge 13 is connected by an air line 23 to a junction 24 which is coupled into a pair of pneumatic NOR gates 25 and 26. Such NOR gates are conventional, for example, being turbulence amplifiers available from the Fluidic Division of the Howie Corp., Norristown, Pa. The junction 24 is connected to the supply tube 27 of the NOR gate 25 and to the supply tube 28 of the NOR gate 26. The collector tube 29 of the gate 25 is connected to the control jet 30 of the gate 26. The tubing 21 from the one-shot sensor valve 15 is connected to the control jet 31 of the gate 25. The collector tube 32 of the gate 26 is connected to a solenoid 33 of the pneumatic amplifier 34 by the air line 35. The pneumatic amplifier 34 is a conventional spring loaded amplifier valve, for example a Model No. 5BV011 available from the Norgren Fluidics Co. of Littleton, Colo. The inlet 36 of valve 34 is connected to the regulated air supply 10 through the air line 11. The outlet 37 of the valve 34 is connected by the air line 38 to an output junction 39 and to a conventional pneumatic counter 40 for counting the number of fluidic impulses appearing in the air line 38.

In the operation of the pneumatic circuitry of FIG. 1, the movement of the pump rod 16 causes the one-shot tank 19 to receive pressurized air from the regulated air supply through the inlet 14 in valve 15. When the pump rod returns to its original position, the air in the one-shot tank 19 passes along the air line 21 to the control jet of the NOR gate 25. Since the NOR gate 25 is a turbulence amplifier, this interrupts the stream of air from the supply tube 27 to the collector tube 29 and thus there is no output appearing in the collector tube 29. This lack of air in the air line between the collector tube 29 and the control jet 30 causes there to be an amount of air passed from the supply tube 28 to the collector tube 32 in the NOR gate 26, this amount of air being determined by the low pressure regulator 12. This impulse of air is then passed along the air tube 35 to control the solenoid 33 in the amplifier valve 34. This causes the regulated air supply 10 to be passed from the inlet 36 to the outlet 37 of the amplifier valve 34 and to thus appear as an impulse of air in the air line 38, the junction 39 and the counter 40. For example, as illustrated, the pump 17 has reciprocated 2,345 times as shown on the counter 40.

Referring now to FIG. 2, the junction 39 is connected to a solenoid 41 of the one-shot storage valve...
One of the inlets 43 of the valve 42 is connected by the air line 44 to the regulated air supply 10. Another orifice 45 in the valve 42 is connected to a one-shot air tank 46. The outlet 47 of the valve 42 is connected to the solenoid 48 of a dump pilot valve 49. The air line 50 which connects the outlet 47 and the solenoid 48 has a slow bleed valve 51 located therein. The inlet orifice 52 of the pilot dump valve 49 is connected to the air line 44. The outlet 53 of the valve 49 is connected to the solenoid 54 of the dump valve 55. Another outlet 56 of the valve 49 is connected to the ambient air for bleeding purposes.

The input junction 39 is also connected by air line 57 to the solenoid 58 of the transfer valve 59. The orifice 60 of the transfer valve 59 is connected to the air time tank 61 which is also connected to the inlet 62 of the dump valve 55. The output orifice 63 of valve 55 is connected to ambient air for dumping the time tank 61. The input orifice 64 of the transfer valve 59 is connected to the output of the flowmeter 65, the regulated air supply 10 and flowmeter 65 being located within the dotted line area 66. The output orifice 67 of the transfer valve 59 is connected to a booster relay 68 which is also connected to the regulated air supply 10 by the air line 69. The output of the booster relay 68 is connected to a pneumatic readout device 70.

The valves 42, 55 and 59 are conventional, for example, the Model No. 316F2-178 In-Val-Co available from the Microvalve Co. of Tulsa, Okla. The pilot dump valve 49 is also conventional, for example, the Model No. 5BV011 available from Norgren Fluidics of Littleton, Colo. The booster relay 68 is also conventional, for example, Model No. GC68A available from Moore Products Co. of Springhouse, Pa.

In the operation of the circuit of FIG. 2, an air impulse appearing at input terminal 39 causes the solenoid 41 to be actuated in the valve 42. This causes the one-shot air tank 46 to receive air from the regulated air supply 10 through the inlet orifice 43. At the completion of the pulse at terminal 39, the spring loaded valve 42 returns to its original position and the air stored in the one-shot tank 46 passes through the output orifice 47 to the solenoid 48 of the pilot dump valve 49. This in turn causes air from the regulated air supply 10 to pass through the input orifice 52 of the pilot dump valve 49 and on to the solenoid 54 of the dump valve 55. At the end of the impulse from the one-shot tank 46, the air in the line 50 then bleeds off through the timing orifice 51 and the solenoid 48 of the pilot dump valve 49 returns to its original position. The air impulse appearing at input terminal 39 is also connected to the solenoid 58 of the transfer valve 59. Prior to the solenoid 58 being actuated, the output of the flowmeter 65, being conventional and delivering air impulses at a predetermined rate, is coupled into the timing tank 61. At the moment the impulse appears on the solenoid 58 from the input junction 39, the air pressure which has been stored in the time tank 61 is then transferred over to the output orifice 67 of the transfer valve 59 and through the booster relay 68 to the readout device 70. The same impulse appearing at junction 39 then sets in motion the action of the one-shot tank 46, the pilot dump valve 49 and the dump valve 55 which then causes the time tank 61 to be dumped through the output orifice 63 of the dump valve 55 into the ambient air. Thus it should be appreciated that in the time between the dumping of the time tank 61 and its transfer to the readout device 70, the time tank 61 is building pressure at a set rate as determined by the flowmeter 65. The time between pulses is then represented by a pressure buildup in the time tank 61. Thus, the pressure in the timing tank 61 at any given time is proportional to the rate of pulses generated by the one-shot sensing valve 15 or the mechanical force of the reciprocating pump rod 16 that causes the one-shot sensing valve 15 to operate.

Referring now to FIG. 3, there is illustrated an alternative embodiment of the dotted line portion 66 of FIG. 2, being identified by the numeral 66. The regulated air supply 10 is connected by the air line 80 to a pneumatic motor 81 having a shaft 82 and a rotating disc 83 attached thereto. Located near the periphery of the disc 83 is a hole 84 therethrough. A pair of air switches 85 and 86 are arranged on opposite sides of the disc 83, i.e., 180° apart. Each of the air switches is arranged on the periphery of the disc such that air passes through each of the switches only when the hole 84 passes through the respective switch. The input side 87 of the switch 85 is connected to the air line 80 and the input side 88 of switch 86 is also connected to the air line 80. The output side 89 of switch 85 is connected to the solenoid 90 of the switching valve 91. Likewise, the output side 92 of switch 86 is connected to the solenoid 93 of the switching valve 94. The inlet orifice 95 of the valve 91 is connected to the air line 80. The outlet orifice 96 of valve 91 is connected to the air volume tank 97 which is also connected to the input orifice 98 of valve 94. The outlet orifice 99 of valve 94 is connected to output terminal 100 which is connected to the inlet orifice 64 of the transfer valve 59 of FIG. 2.

The air line 80 is also connected to output terminal 101 which is connected to the relay 68 in FIG. 2. It should be appreciated that the air switches 85 and 86 are conventional, for example, Model No. 4JS-020-D00 available from Norgren Fluidics of Littleton, Colo. Likewise, the switches 91 and 94 are conventional, for example, being available as Model No. 5BV011 from Norgren Fluidics of Littleton, Colo.

In the operation of the embodiment of FIG. 3, the regulated air supply 10 causes the pneumatic motor 81 to rotate at a constant speed. This causes the hole 84 in the disc 83 to activate the air switch 85 each time the hole 84 passes therethrough. Each time this happens, the solenoid 90 causes the valve 91 to be activated, thus causing the regulated air supply to pressurize the air volume tank 97. As the disc 83 rotates, this activates the air switch 86 which in turn activates the valve 94, causing the volume tank 97 to be discharged through the output terminal 100 and into the time tank 61 of FIG. 2. Thus, it should be appreciated that this supplies a means of digitally charging the time tank 61 of FIG. 2. Since the speed of the motor 81 is held constant, the repeated transfer of the air from the volume tank 97 into the time tank 61 causes the air pressure within the time tank 61 to be increased at a known rate.

While the preferred embodiments of the present invention have been described and illustrated herein, a careful reading of the foregoing specification and drawing will enable those skilled in the art to make obvious modifications thereof. For example, whereas there has
been illustrated and described improved circuitry for counting the number and rate of air impulses resulting from the movement of reciprocating rods such as that associated with pumps and the like, it should be appreciated that one could if desired take the output directly from the one-shot sensor valve 15 into the junction 39 if the pressures are adequate for the purposes desired. Furthermore, it should be appreciated that the rate output indication on the indicator 70 can be combined and correlated with any number of variables, for example, depth, rate of penetration, or the like for use in the drilling of oil and gas wells. By way of specific example, if the indicator 70 is a continuous recorder driven in response to drilling depth, it becomes quite simple to measure and record mud pump strokes per foot of drilled depth. It should also be appreciated that the relay 68 can be so-called "inversing" type relay which causes a reduced output for an increased input, such as is useful for measuring the rate of impulses directly.

Furthermore, if desired, the pneumatic circuit illustrated and described with respect to FIG. 2 can be modified such that the air pressure in the time tank 61 is varied in the other direction, i.e., decreased following each impulse. With such an arrangement, the timing tank is initially pressurized to a known value and then allowed to bleed down until the occurrence of an air impulse of interest. The pressure in the tank at that moment is thus nonetheless indicative of the time between impulses. For example, if it is known that the pressure in the tank decreases from 45 p.s.i. to 30 p.s.i. in 10 seconds, a reading of 30 p.s.i. indicates that the pulses are 10 seconds apart at the time of measurement.

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

1. A ratemeater apparatus for monitoring the rate of air impulses in a pneumatic air line, comprising:
   means providing said impulses to said line;
   an air storage tank;
   a pressure responsive display means;
   means supplying a controlled rate of air pressure;
   gate means responsive to said impulses to connect said tank to said display means and responsive to the absence of said impulses to connect said pressure supply means to said tank;
   and a normally closed dump means responsive to said impulses to dump said tank after the completion of each of said impulses.

2. The apparatus according to claim 1 wherein said means dump comprises:
   a second air storage tank;
   means to store pressurized air in said second storage tank at the beginning of said impulses;
   a pneumatic main dump valve connected to said air timing tank; and
   means to utilize the air stored in said second storage tank to activate said dump valve coincident with the termination of said impulses.

3. The apparatus according to claim 2 wherein said means to utilize the air stored in said second storage tank comprises:
   a pneumatic storage valve connected to said second storage tank and activatable by said air impulses;
   a pneumatic pilot dump valve connected to the outlet port of said storage valve and activatable by the air stored in said second storage tank, the inlet port of said pilot dump valve being connected to a source of pressurized air and the outlet port of said pilot dump valve being connected to said main dump valve.

4. The apparatus according to claim 1 wherein said means comprises:
   a constant speed motor having a rotating disc attached thereto, said disc having an opening therethrough near its periphery;
   a first and a second air switch, each being supplied with a source of pressurized air, arranged on the periphery of said disc whereby the opening in the disc alternately activates said first and second air switches while rotating;
   a first pneumatic valve attached to and activatable by said first air switch;
   a second pneumatic air valve attached to and activatable by said second air switch;
   a source of pressurized air connected to the inlet port of said first pneumatic valve; and
   an air volume tank connected to the outlet port of said first valve and to the inlet port of said second valve, whereby a given volume of pressurized air appears at the outlet of said second valve for each rotation of said disc.

5. The apparatus according to claim 4 wherein said first and second air switches are arranged 180° apart with respect to said disc.

6. A pneumatic counting apparatus for monitoring the reciprocating strokes of a pump, comprising:
   a pneumatic sensing valve attached to the reciprocating shaft of said pump and activatable thereby;
   a regulated air supply attached to the inlet port of said sensing valve;
   a one-shot storage air tank connected to one of the ports in said sensing valve and arranged to be supplied with air from said air supply when said sensing valve is activated;
   pneumatic gating means connected to the outlet port of said sensing valve, the gating means being supplied by a source of air having a pressure lower than said regulated air supply;
   a pneumatic amplifier valve connected to the output of said gating means and to said regulated air supply, whereby the pneumatic amplifier valve provides a single impulse of air for each stroke of said pump; and
   counter means connected to the output of said amplifier valve for counting said impulses.

7. A pneumatic ratemeater and counting apparatus for monitoring the reciprocating strokes of a pump, comprising:
   a pneumatic sensing valve attached to the reciprocating shaft of said pump and activatable thereby;
   a regulated air supply attached to the inlet port of said sensing valve;
   a one-shot storage air tank connected to one of the ports in said sensing valve and arranged to be supplied with air from said air supply when said sensing valve is activated;
   pneumatic gating means connected to the outlet port of said sensing valve, the gating means being sup-
applied by a source of air having a pressure lower than said regulated air supply;
a pneumatic amplifier valve connected to the output of said gating means and to said regulated air supply, whereby the pneumatic amplifier valve provides a single impulse of air for each stroke of said pump;
an air storage timing tank;
means for causing the air pressure within said timing tank to vary at a predetermined rate;
means to monitor the amount of air pressure within said timing tank coinciding with the occurrence of said air impulses; and
means to return the air pressure within said timing tank following said impulses to the pressure present in said tank prior to the occurrence of said impulses.
8. The apparatus according to claim 7 including in addition thereto counter means connected to the output of said amplifier valve for counting said impulses.
9. The apparatus according to claim 8 wherein said gating means comprises a first pneumatic NOR gate having its control jet connected to the outlet port of said sensing valve and its collector tube and a second pneumatic NOR gate having its control jet connected to the collector tube of said first NOR gate.

* * * *