

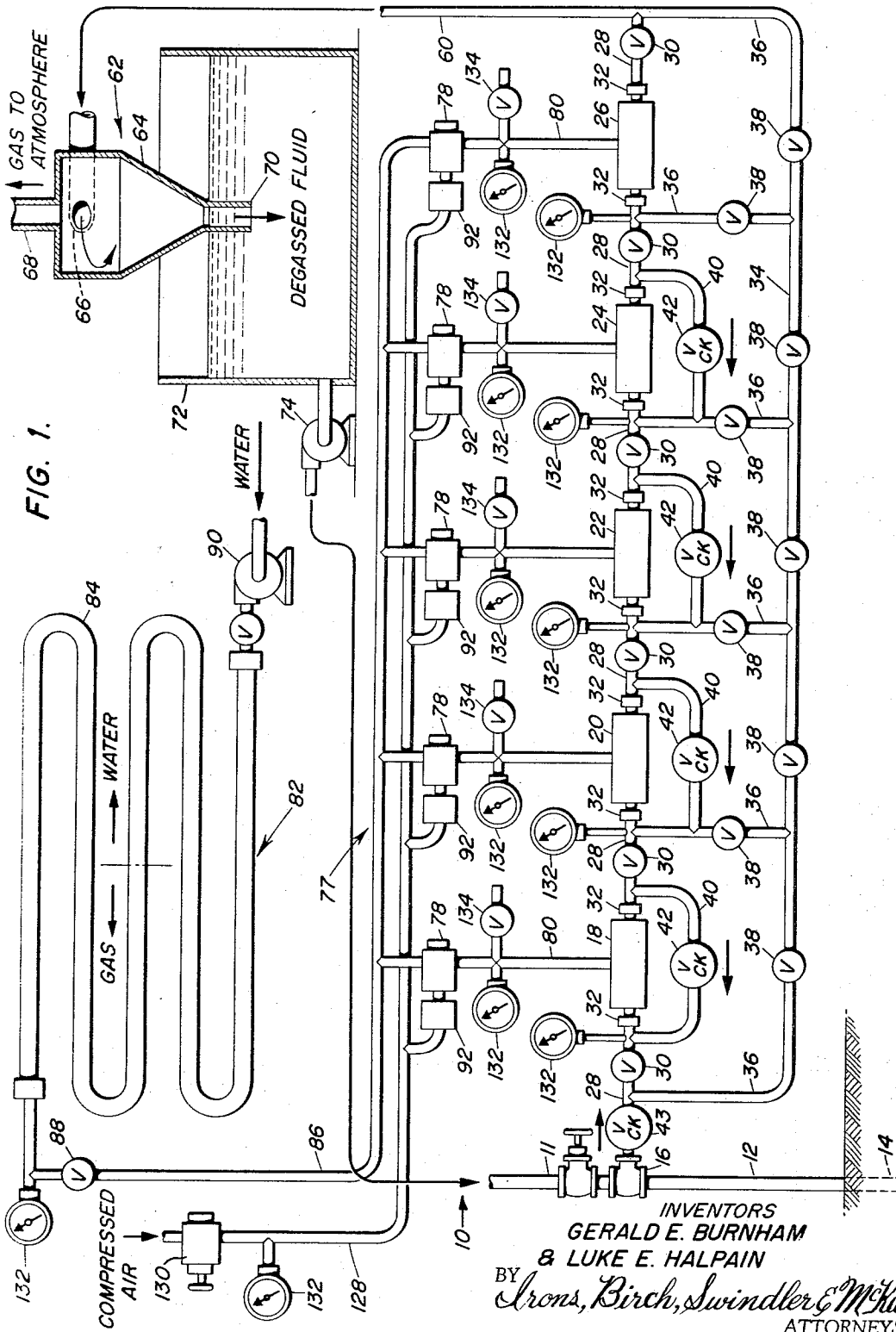
Jan. 23, 1968

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DRILLING FLUID CIRCULATION SYSTEM HAVING
FLOW PARAMETER REGULATING MEANS

3,365,009

Filed July 12, 1966

2 Sheets-Sheet 1



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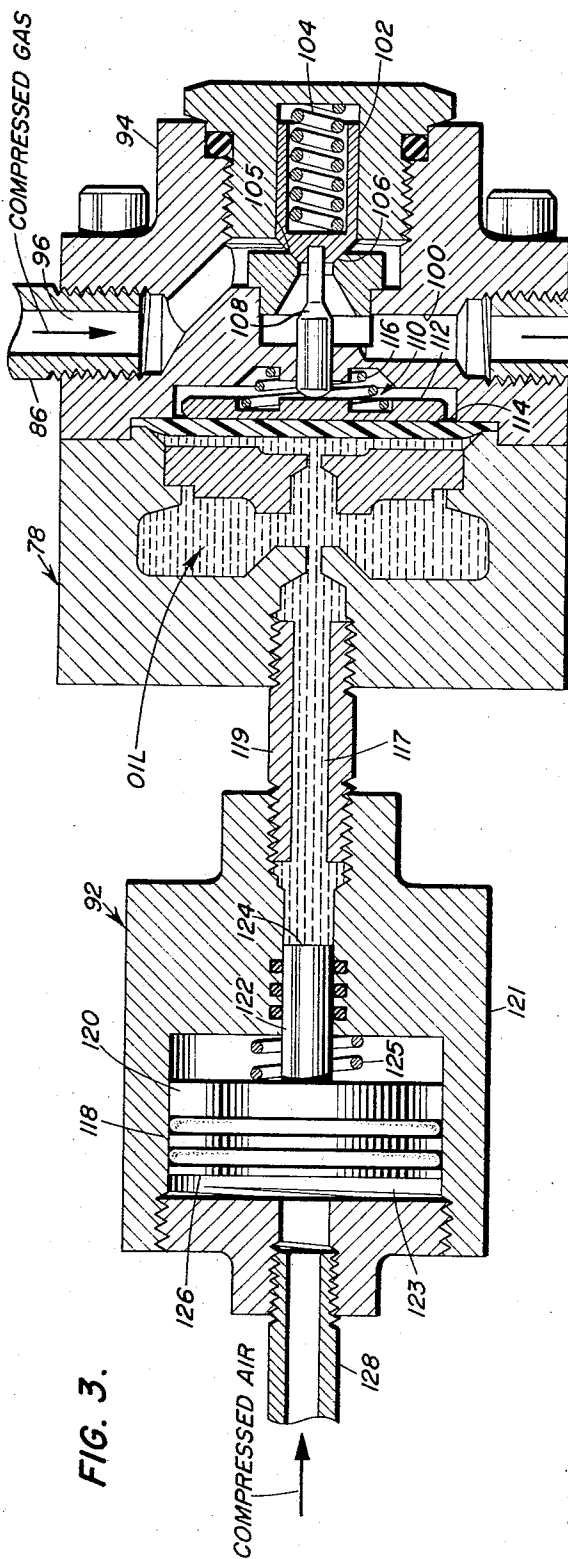


FIG. 3.

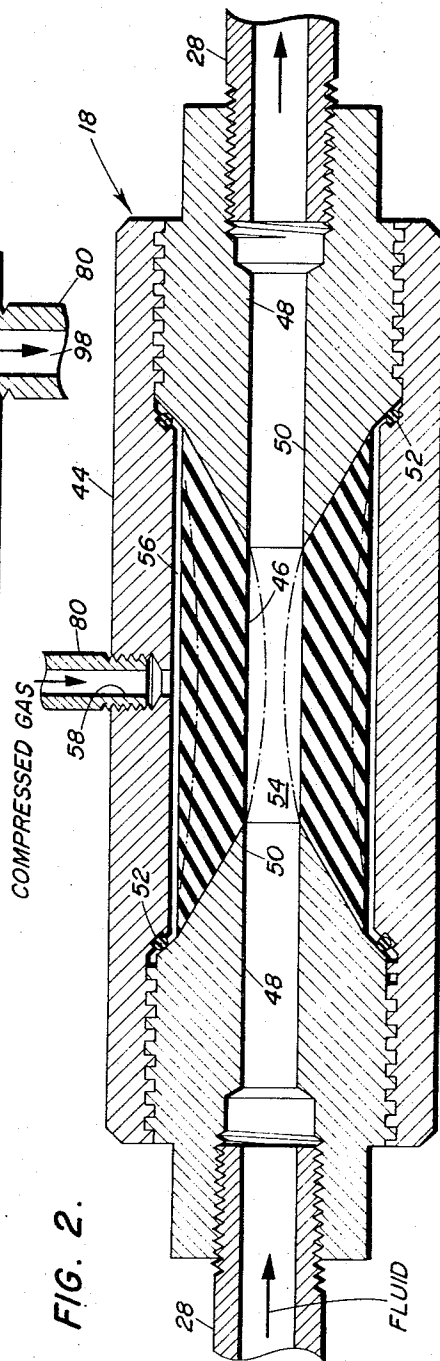


FIG. 2.

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DRILLING FLUID CIRCULATION SYSTEM
HAVING FLOW PARAMETER REGULATING MEANS

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This invention relates to a drilling fluid circulation system having integral means for regulating the important flow parameters of a drilling fluid subjected to high pressures from within an oil well during a well drilling operation. Specifically, the invention concerns a drilling fluid circulation system incorporating a plurality of serially connected bladder valves and means for actuating the valves simultaneously, for controlling the flow rate and pressure of drilling fluid emanating from an oil well under the impetus of high pressure gas.

Frequently, in an oil well drilling operation, a high pressure pocket of gas is encountered incident to the penetration of a subsurface earth formation which seriously impairs the safety and efficiency of the drilling operation. In order to prevent the high pressure gas from venting uncontrollably to the surface through the well casing, it has been the common practice to provide an orifice in the drilling fluid circulation system through which drilling fluid emanating from the well is directed for restricting the flow of highly pressurized fluid out of the well and to seal the well by closing the blowout preventers. Since the rotary drilling operation cannot be continued while the well is thus sealed, due to the closing of the blowout preventers onto the drill pipe, additional amounts of drilling fluid are thereafter pumped into the well to increase the hydrostatic pressure above the gas so that the gas pressure may be controlled without necessitating the continued closure of the blowout preventers. One of the problems inherent in the foregoing procedure resides in the frequent clogging of the orifice in the circulation system with pieces of shale or rock carried to the surface by the drilling fluid from the bottom of the well. Upon the clogging of the orifice the continued circulation of drilling fluid becomes impossible and therefore no means exist for alleviating the gas pressure within the well. Consequently, as long as the blowout preventers are closed, and the fluid circulation system is inoperative to permit the flow of fluid out of the well, there exists a possibility that the high pressure gas will rupture the formation resulting in a sudden loss of substantial amounts of drilling fluid into the formation. The sudden loss of hydrostatic pressure on the gas following the escape of drilling fluid into the formation subjects the well casing and drill pipe to a sudden increase in gas pressure that can result in a blowout, posing a serious danger both to men and equipment. Obviously it is undesirable to operate under such conditions both from an economic and a safety point of view.

The drilling fluid circulation system of the present invention includes an integral flow parameter regulating apparatus which substantially obviates the difficulties posed by the presence of high pressure gas encountered during oil well drilling operations. The flow parameter regulating apparatus includes a plurality of serially connected bladder valves which are connected to the source of drilling fluid emanating from an oil well during a drilling operation. The bladder valves sequentially reduce the pressure of the fluid flowing out of the well under the impetus of high pressure gas to the pressure desired for achieving a particular fluid flow rate. The pressure ratio across a single bladder valve is maintained well within the operating tolerances of the valve to preclude the possibility of structural failure that might occur should a single valve be

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used for effecting the total pressure reduction required. The pressure reducing effect of each valve contributes to the sum of the total pressure reduction effected across the plurality of valves. The pressure reduction capability available across the plurality of bladder valves is sufficient to reduce the pressure of the drilling fluid to an appropriate level for achieving the desired drilling fluid flow rate from the well.

The interior passage through each of the bladder valves is large enough to accommodate the flow therethrough of the solid materials normally expected to be carried to the surface by the drilling fluid. In addition, the bladder closure member of each valve is formed of a resilient material which "gives" or flexes outwardly whenever large particles of solid materials in the drilling fluid impact thereagainst, to thus permit the passage of large pieces of rock and shale through the valves without obstructing the flow of fluid from the well. The problem of clogging inherent in the use of conventional circulation systems having a flow-restricting orifice is thus precluded.

The bladder valves are actuated and regulated by a pneumatic control system which automatically closes each bladder valve appropriately for obtaining the desired pressure reduction thereacross. The control system may be regulated by a single control valve to adjust the bladder valves in accordance with the pressure of the drilling fluid emanating from the well.

The drilling fluid circulation system of the invention also includes a gas separating means connected to the plurality of bladder valves downstream of the valves for receiving the drilling fluid at an optimum flow rate after the pressure thereof has been reduced by passage through the valves. The separating means comprises a cyclone separator which liberates gas entrained in the drilling fluid as the fluid passes therethrough, and a storage tank in which the drilling fluid is stored for recirculation back into the well.

With the foregoing in mind, it is a primary object of the present invention to provide a drilling fluid circulation system having an integral flow parameter regulating apparatus which permits a well drilling operation to be conducted in a safe and efficient manner in the presence of high pressure gas pockets encountered incident to the penetration of subsurface earth formations.

It is a further object of the invention to provide a flow parameter regulating apparatus for use in a drilling fluid circulation system wherein the regulating apparatus comprises a plurality of serially connected bladder valves which may be actuated by a single control command to sequentially reduce the pressure of a high pressure flow of drilling fluid for achieving an optimum drilling fluid rate.

It is an additional object of the invention to provide a drilling fluid flow parameter regulating apparatus which effectively regulates the pressure and flow rate of a highly pressurized flow of drilling fluid in which are entrapped particles of solid materials.

Another object of the invention is to provide a drilling fluid circulation system having an integral flow parameter regulating apparatus for controlling the flow rate and pressure of the drilling fluid emanating from a well and a gas separating means for liberating gas entrained in the fluid prior to recirculation of the fluid back into the well.

The above and more specific objects of the drilling fluid circulation system of the present invention will be apparent from the following description of a preferred embodiment thereof given in conjunction with the following drawings, in which:

FIG. 1 is a schematic view of the drilling fluid circulation system of the invention;

FIG. 2 is a sectional view of one of the bladder valves of the flow parameter regulating apparatus used in the circulation system shown in FIG. 1; and

FIG. 3 is a sectional view of two of the components of the pneumatic control system used for actuating and regulating the bladder valve shown in FIG. 2.

Referring to the drawings, there is shown schematically in FIG. 1 the drilling fluid circulation system 10 of the present invention. Circulation system 10 is connected to the source of drilling fluid emanating from an oil well such as through a well casing 12. Positioned concentrically within casing 12 and extending therethrough to the bottom of the well is a string of drill pipe 11 for rotatably driving a drill bit (not shown) affixed to the lower end thereof. Casing 12 extends into the bore hole 14 of the well and carries drilling fluid from the bottom of the well upward in the annular space defined between the casing and drill pipe 11 to a fitting 16 which connects circulation system 10 to the well. The drilling fluid flows through casing 12 and fitting 16 into circulation system 10 under extremely high pressure whenever a pocket of high pressure gas is encountered at the bottom of bore hole 14 incident to the penetration of a gas-filled subsurface formation.

Fitting 16 is connected to casing 12 below the blowout preventers (not shown), so that the preventers may be closed as required for sealing the well to retain the gas therein, without interfering with the operation of circulation system 10. The rotary drilling operation cannot be continued while the blowout preventers are closed onto drill pipe 11. However, the operation of circulation system 10 ensures that drilling fluid will be continuously circulated through the well to alleviate the gas pressure therein and to permit the accumulation of drilling fluid above the gas, for increasing the hydrostatic pressure in the well to a magnitude sufficient to control the gas pressure therein, so that the blowout preventers may be reopened.

Circulation system 10 includes an integral flow parameter regulating apparatus comprising a plurality of serially connected bladder valves 18, 20, 22, 24 and 26 for accommodating the flow of pressurized drilling fluid therethrough after the fluid leaves well casing 12 through fitting 16. The regulating apparatus shown in FIG. 1 includes five bladder valves but it is apparent that more or less could be used as required. The bladder valves are connected together by a plurality of pipe sections 28. Additional pipe sections 28 connect the upstream valve 18 to fitting 16 and the downstream valve 26 to a delivery pipe 60 through which the drilling fluid flows after serially passing through the valves 18, 20, 22, 24 and 26. Interposed between each of the bladder valves, between valve 18 and fitting 16 and between valve 26 and delivery pipe 60 is a manually operable cut-off valve 30. The bladder valves are connected to pipe sections 28 by quick-disconnect couplers 32 so that the bladder valves may be replaced or repaired as required by simply disconnecting the couplers 32 of a particular bladder valve without necessitating the disassembly of the entire apparatus. In order to permit a particular bladder valve to be isolated for repair or replacement as required, a bypass pipe 34 is provided which communicates with each side of the respective bladder valves by a plurality of connecting pipes 36. Bypass pipe 34 and connecting pipes 36 include appropriate shut-off valves 38 which may be adjusted in conjunction with valves 30 to provide a bypass around any particular one of the bladder valves 18, 20, 22, 24 or 26, as required.

A return flow pipe 40, including a one-way check valve 42, is connected in parallel with each of the bladder valves 18, 20, 22 and 24 to permit drilling fluid to flow back around the bladder valves toward well casing 12 instead of through the valves in the event of a sudden pressure reduction within the well. In addition, a check valve 43 is interposed between bladder valve 18 and fitting 16 which isolates the bladder valves from the well upon the occurrence of a reverse flow condition, thus permitting the pressure across all of the bladder valves to equalize

very quickly in the event of a sudden pressure reduction within the well. This feature of the apparatus ensures that a sudden pressure reduction upstream of the valves will not subject the individual valves to a pressure ratio which might exceed the failure strength of the valve materials. A return flow pipe and check valve are not required for valve 26 inasmuch as the absolute pressure of the fluid passing through this valve will never exceed the failure strength of the valve materials.

The construction of bladder valve 18 is shown in FIG. 2, which is identical to the construction of the other bladder valves 20, 22, 24 and 26, rendering unnecessary therefore a detailed description of the construction of the latter valves. Bladder valve 18 comprises a valve body 44 having a cylindrically shaped internal chamber within which is positioned an annular resilient bladder 46. Bladder 46 is retained within valve body 44 by a pair of retaining members 48 having conically shaped end portions 50 which engage the bladder ends. Retaining members 48 also threadingly engage the open ends of valve body 44 to seal the valve and provide a compact construction. A resilient O-ring 52 is interposed between each retaining member 48 and valve body 44 to provide a fluid-tight seal between the elements of the valve.

Valve 18 has a central longitudinal passage 54 therethrough which passes through retaining members 48 and resilient bladder 46. Pressurized drilling fluid from the well having gas entrained therein enters the valve from the lefthand side thereof, as shown by the arrow in FIG. 2, and passes therethrough, exiting from the righthand side of the valve. A bladder actuating chamber 56 is defined between the internal chamber within valve body 44 and resilient bladder 46. Chamber 56 receives compressed gas therein through an aperture 58 in valve body 44 for flexing resilient bladder 46 as required to achieve the desired sized central passage 54 through the bladder. The pressure ratio across valve 18 is determined by the size of passage 54 through bladder 46, and is therefore dependent upon the degree to which the bladder is flexed inwardly by the compressed gas received within chamber 56. The pressure of the compressed gas introduced into chamber 56 is regulated by a pneumatic control system described in detail hereinafter.

Often in the process of drilling an oil well, a high pressure pocket of gas is encountered which exerts a large force upwardly on the drilling fluid and which becomes entrained in the fluid, both of which factors cause a substantial increase in the pressure of the drilling fluid. In such a situation, drilling fluid pressures of 10,000 pounds per square inch are not uncommon. In the operation of circulation system 10, as the high pressure fluid flows upwardly through well casing 12 and fitting 16, it passes into the serially connected bladder valves 18, 20, 22, 24 and 26. As it flows through the bladder valves, the pressure of the fluid is sequentially reduced to achieve an optimum drilling fluid flow rate. The pressure ratio across each one of the individual bladder valves is maintained at a level such that the magnitude of the absolute pressure reduction across the valve is below the structural failure limit of resilient valve bladder 46. A pressure reduction of 10,000 pounds across any one valve would rupture the best resilient bladder material presently known. However, by maintaining the pressure reduction across each valve within the tolerable limits of the bladder material, such as a 2,000 pound absolute pressure differential across each bladder, a drilling fluid flow pressure of 10,000 pounds may be controlled effectively and reduced as required for achieving the desired flow rate of fluid from valve 26, this valve being the last pressure reduction stage in the series of valves.

The size of passage 54 through bladder 46 is large enough to permit pieces of shale or rock entrapped in the drilling fluid to pass therethrough without disrupting the flow of drilling fluid. Furthermore, when impacted by large solid particles bladder 46 flexes outwardly due to

the resiliency of the bladder material and the cushioning effect of the compressed gas in chamber 56 surrounding the bladder, to permit the particles to pass therethrough instead of clogging the bladder and obstructing the fluid flow therethrough. The size of passage 54 is selected to be of a diameter large enough to allow the passage therethrough of the largest particles expected to be entrapped in the drilling fluid. Normally such particles are no larger than three-fourths of an inch thick.

The depressurized fluid passes from valve 26 into delivery pipe 60 for passage to a gas separating means 62. Separating means 62 comprises a cyclone separator 64 having a drilling fluid inlet 66 tangentially connected to the upper portion thereof. Drilling fluid enters cyclone separator 64 through inlet 66, and as the fluid passes through the separator, gas entrained therein is liberated to the atmosphere through a vent 68 at the top of the separator. The degassed fluid passes through the separator and flows out under the influence of gravity through a discharge outlet 70 in the bottom thereof into a drilling fluid storage tank 72. The level of drilling fluid in tank 72 is kept well above the lower end of outlet 70 to ensure that air will not be entrained in the drilling fluid after it has passed through cyclone separator 64. A high pressure pump 74 removes the drilling fluid from storage tank 72 as required for recirculation back into the well through drill pipe 11.

Operation of the bladder valves is controlled by a pneumatic control system 77 which regulates the introduction of compressed gas into the bladder actuating chamber 56 of each of the valves 18, 20, 22, 24 and 26. Control system 77 includes a plurality of pressure regulators 78, one of which is connected to each of the valve bodies 44 of the bladder valves by a junction pipe 80. Compressed gas is metered from regulators 78 through junction pipes 80, and into the bladder actuating chambers 56 of valves 18, 20, 22, 24 and 26 for flexing the resilient bladders 46 therein as required for obtaining an optimum drilling fluid flow rate.

Regulators 78 also communicate with a source of compressed gas 82 which supplies compressed gas to the regulators to be metered therethrough into bladder actuating chambers 56. Compressed gas source 82 includes a manifold 84 connected to the regulators 78 by a pipe 86 in which is interposed a manual control valve 88. A compressible gas, such as nitrogen, is introduced into manifold 84 which is thereafter sealed to form a closed pneumatic system between the manifold and bladder actuating chambers 56. In order to raise the pressure of the gas within manifold 84 to a level sufficient to flex the bladders 46 against the force exerted thereon by the pressurized drilling fluid, a substantially incompressible liquid, such as water, is pumped into the manifold by means of a high pressure pump 90 for decreasing the volume within the manifold available for containment of the gas, thereby increasing the pressure of the gas. The pressure of the compressible gas within manifold 84 thus may be controlled to provide sufficient pressure within bladder actuating chambers 56 to effect the desired closing of resilient bladders 46.

Regulators 78 which meter the flow of compressed gas from manifold 84 into the bladder actuating chambers 56 are controlled by a plurality of expansible chamber means 92, one such expansible chamber means being connected to each pressure regulator 78. The internal structure of one of the pressure regulators 78 and associated expansible chamber means 92 is shown in FIG. 3. Regulator 78 includes a housing 94 having an inlet 96 that is connected to pipe 86 through which compressed gas is received from manifold 84. Housing 94 also includes an outlet 98 which communicates with bladder actuating chamber 56 through junction pipe 80. Inlet 96 communicates with outlet 98 by means of an internal passage 100 within housing 94. A control valve 102 is interposed in passage 100 to meter the flow of compressed

gas through regulator 78. Valve 102 is biased toward the closed position by a compression spring 104 which urges the conically shaped head portion 105 of the valve against a stationary valve seat 106. Valve 102 also includes a valve stem 108 which is affixed to head portion 105 of the valve and extends therefrom toward a valve operator assembly 110. Operator assembly 110 comprises a plate 112 and a resilient diaphragm 114 adjacent one side thereof. The end of valve stem 108 terminates adjacent the other side of plate 112. Operator assembly 110 also includes a compression spring 116 which engages plate 112 and urges the plate and diaphragm 114 to the left as seen in FIG. 3, away from valve stem 108. When operator assembly 110 is depressed against the force of spring 116, plate 112 engages valve stem 108 and moves the stem to the right, to unseat valve 102 against the force of compression spring 104. As head portion 105 of valve 102 moves to the right away from valve seat 106, compressed gas is permitted to flow through internal passage 100 from inlet 96 to outlet 98 as shown by the arrows in FIG. 3.

Actuation of valve operator assembly 110 is controlled by expansible chamber means 92. A closed fluid chamber 117 is defined by fluid-receiving recesses formed in the case 121 of expansible chamber means 92 and the housing 94 of regulator 78, which recesses communicate through a pipe section 119 connected therebetween. Resilient diaphragm 114 forms one wall of the fluid-receiving recess formed in housing 94. Chamber 117 is completely filled with a control responsive fluid which acts against resilient diaphragm 114 of the valve operator assembly 110. The control responsive fluid preferably is a substantially incompressible liquid such as oil. It will be seen that resilient diaphragm 114 will be displaced to the right whenever pressure is applied to the fluid within chamber 117 to thereby urge plate 112 into engagement with valve stem 108 and thus open valve 102.

A movable control member 118 is positioned within case 121 and comprises a piston 120 and a plunger 122 affixed to one side thereof. The end 124 of plunger 122 defines one wall of fluid chamber 117. Movement of plunger 122 toward housing 94 causes the incompressible control responsive fluid within chamber 117 to exert a force acting to the right on resilient diaphragm 114 to depress valve operator assembly 110 and unseat valve 102.

Movement of plunger 122 is controlled by the sliding movement of piston 120 within case 121. One end 126 of piston 120 defines within case 121 a chamber 123 for receiving therein a control fluid for regulating the movement of piston 120 and plunger 122 affixed thereto. The control fluid, preferably compressed air taken from the oil well rig air compressor, is delivered to control fluid chamber 123 through a pipe 128 connected to case 121. By controlling the pressure of the control fluid introduced into chamber 123, the movement of piston 120 may be regulated, which in turn regulates the movement of plunger 122. A compression spring 125 engages piston 120 and biases the piston and integral plunger 122 to the left so that a control fluid pressure greater than atmospheric will be required to displace member 118 to the right for opening valve 102. The pressure of the control fluid introduced into the chamber 123 of all of the expansible chamber means 92 may be adjusted by a single manually operable control valve 130 to thus simultaneously control the movement of all of the control members 118. In this manner a single control command effectively regulates the actuation of bladder valves 18, 20, 22, 24 and 26 simultaneously.

In order to achieve the desired sequential pressure reduction across the individual bladder valves 18, 20, 22, 24 and 26, the bladder 46 within each of the valves must be individually adjusted to accommodate the different drilling fluid pressure applied thereto. The pressure of the compressed gas within bladder actuating chamber 56 of

valve 18 must be of a greater magnitude than the pressure of the gas in actuating chamber 56 of valve 20 since the absolute pressure of the drilling fluid flowing through valve 18 will be greater than the absolute pressure of the fluid flowing through valve 20. Similarly, the compressed gas pressure within the bladder actuating chambers 56 of each of the succeeding valves 22, 24 and 26, which are progressively further downstream from the well, must be decreased proportionately in accordance with the pressure decrease of the drilling fluid flowing therethrough. Thus, pressure regulator 78 connected to valve 18 must permit a larger volume of compressed gas to flow into the actuating chamber 56 of this valve than the regulator 78 associated with valve 20 permits to flow into the actuating chamber 56 of that valve, and so on for each of the remaining bladder valve-regulator combinations progressively further downstream from the well. In order to obtain this result, valves 102 of the regulators 78 which are connected to the bladder valves closest to the source of drilling fluid emanating from the well must be open for a greater length of time than the valves 102 of the regulators 78 associated with the bladder valves more distant from the source of fluid.

The movable control member 118 of each of the expandable chamber means 92 is designed, therefore, to effectuate the desired operation of the individual regulator valves 102 in accordance with the compressed gas requirement of the particular bladder valve associated therewith. The piston surface 126 of the control member 118 associated with bladder valve 18 is of a greater area than the similar surface associated with bladder valve 20. Similarly the piston surface 126 of each control member 118 associated with each of the bladder valves progressively more distant from the source of drilling fluid is of a reduced area. The plunger surfaces 124, however, are of substantially the same area for each of the control members 118.

From the above description it will be apparent that for a particular control fluid pressure magnitude, a greater force will be exerted on piston surface 126 of the control member 118 which is associated with bladder valve 18 than on the surface 126 of the members 118 associated with the valves progressively more distant from fitting 16. Due to the different force applied to each of the control members 118, a different amount of movement will be imparted simultaneously to each of the individual control members, resulting in a different time period during which each of the valves 102 will remain open. In this manner, the pressure of the compressed gas within each of the bladder actuating chambers 56 will be of a lesser magnitude for each succeeding bladder valve more distant from the well, to thereby provide the appropriate pressure within chambers 56 for obtaining the desired pressure ratio across each of the individual bladder valves without subjecting any one of the bladders 46 therein to an intolerably high absolute pressure reduction differential. The pressure of the drilling fluid emanating from the well will be sequentially reduced by each of the bladder valves, the sum of such pressure reductions producing the total reduction differential required for obtaining an optimum drilling fluid flow rate.

For monitoring the operation of circulation system 10, a plurality of pressure gauges 132 are provided in appropriate locations throughout the system. Also, bleed valves 134 are connected to each of the junction pipes 80 to relieve the pressure within actuating chambers 56 after the pressure of the drilling fluid emanating from the well has subsided to atmospheric or near-atmospheric pressure, requiring limited or no flow parameter regulation for obtaining the desired flow rate from the well.

From the foregoing, it will be appreciated that the drilling fluid circulation system of the invention, including the integral flow parameter regulating apparatus, provides an effective and safe means for regulating the recirculating flow of drilling fluid whenever high pressure gas is en-

countered in the well incident to the penetration of a sub-surface gas-filled formation. The system is relatively easy to install, simple to operate and adaptable to a wide variation of drilling fluid flow requirements.

It is to be understood that the invention is not to be limited to the specific description of the preferred embodiment given hereinabove, but is to be limited solely by the scope of the appended claims.

What is claimed is:

1. In a drilling fluid circulation system a flow parameter regulating apparatus comprising;

a plurality of serially connected bladder valves communicating with means for delivering pressurized drilling fluid from a well, each said valve including a valve body and a flexible bladder mounted therein having a central longitudinal passage therethrough for accommodating the flow of pressurized drilling fluid through said valve, said valve body and said bladder defining therebetween a bladder actuating chamber for receiving compressed gas therein to flex said bladder and vary the size of said central passage;

a pressure regulator communicating with each said bladder actuating chamber for regulating the gas pressure within the actuating chamber to thereby control the size of said central passage;

a source of compressed gas communicating with each said pressure regulator for supplying compressed gas to the regulator to be metered into the bladder actuating chamber communicating therewith;

an expandable chamber means connected to each said pressure regulator and including a movable control member mounted therein for operably controlling the flow of compressed gas metered through said regulator; and

means for simultaneously imparting a different amount of movement to each said control member so that a different volume of compressed gas flows through each said pressure regulator to thereby provide a different size central passage through the bladder of each of said plurality of valves.

2. The flow parameter regulating apparatus as recited in claim 1 wherein;

said control member includes a first fluid contacting surface and a second fluid contacting surface, said first surface defining within said expandable chamber means a first fluid chamber for receiving a control fluid therein, said second surface defining within said expandable chamber means a recess, said recess communicating with said pressure regulator to define therebetween a second fluid chamber for receiving a control responsive fluid therein for acting against a portion of said regulator to control the flow of compressed gas metered through said regulator; and said movement imparting means includes a source of variable pressure fluid communicating with said first fluid chamber for supplying control fluid to said first chamber for controlling the movement of said member.

3. The flow parameter regulating apparatus as recited in claim 2 wherein said first fluid contacting surface of each said control member is of a different area than the first surface of every other control member and said second fluid contacting surface of each said control member is of substantially the same area as the second surface of every other control member.

4. The flow parameter regulating apparatus as recited in claim 3 wherein said control member comprises a piston and a plunger affixed to one side of said piston, said first fluid contacting surface being formed on said piston and said second fluid contacting surface being formed on said plunger.

5. The flow parameter regulating apparatus as recited in claim 2 wherein said control fluid comprises a compressed

sible gas and said control responsive fluid comprises a substantially incompressible liquid.

6. The flow parameter regulating apparatus as recited in claim 1 wherein said pressure regulator comprises;

a housing having an inlet communicating with said source of compressed gas, an outlet communicating with said bladder actuating chamber and an internal passage connecting said inlet and said outlet;

a control valve within said internal passage interposed between said inlet and said outlet for metering the flow of compressed gas from the source of compressed gas through the regulator to the bladder actuating chamber; and

a valve operator associated with said control valve and operably communicating with said expansible chamber means for actuating said control valve in response to commands received from the expansible chamber means.

7. The flow parameter regulating apparatus as recited in claim 1 wherein said source of compressed gas comprises a manifold for receiving controlled amounts of a compressible gas and a liquid therein, said manifold being connected to each said pressure regulator for supplying compressed gas therethrough to each said bladder actuating chamber; and

pumping means communicating with said manifold for controlling the input of said liquid into the manifold

and thereby regulating the pressure of said compressible gas therein.

8. A drilling fluid circulation system comprising the flow parameter regulating apparatus as recited in claim 1 and a gas separating means connected to said plurality of bladder valves for liberating gas entrained in said drilling fluid and recovering the drilling fluid substantially free of entrained gas for recirculation back into said well.

9. The drilling fluid circulation system as recited in claim 8 wherein said separating means comprises a cyclone separator having a drilling fluid inlet connected tangentially to the periphery thereof.

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