FLUID CONTROL APPARATUS

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Field of Search 166/53; 137/488, 1; 175/25, 175/38, 65, 251/122

References Cited

UNITED STATES PATENTS
1,645,601 10/1927 Lee 251/122
3,028,815 4/1962 Canalizo 137/488 X
3,443,643 5/1969 Jones 175/25
3,485,474 12/1969 Baumann 251/121
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ABSTRACT

A method and apparatus for controlling fluid flow from a variable pressure source by a housing which is provided with an inlet for receiving flow from a variable pressure source and an outlet for discharging flow from the housing. Flow constrictor means are mounted within the housing in the form of spaced orifice plates defining flow chambers therebetween. A double acting ram is provided with a conical member mounted thereon with its apex pointed upstream to position the conical member within the orifice plates and chambers defined therebetween to stepwise reduce the pressure and velocity of the variable pressure source.

Means measure the pressure of the variable pressure source at the housing inlet and operate valve means and motor means so that the ram with the conical member thereon may be positioned longitudinally relative to the orifice plates and chambers in response to the pressure of the source measured at the housing inlet to thereby restrict flow from the variable source through the housing. The ram is sealably and movably mounted within the housing so that the fluid medium which controls its position, while acting in response to the variable pressure from the source at the housing inlet does not comingle with the fluid pressure from the source during its passage from the inlet to the discharge end of the housing.

3 Claims, 4 Drawing Figures
FLUID CONTROL APPARATUS
CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of my prior copending application filed on Nov. 3, 1971 bearing Ser. No. 195,250, now abandoned, for "Adjustable Drilling Fluid Choke with Progressive Reduced Pressure zones."

DISCUSSION OF PRIOR ART

The prior art with which applicant is familiar comprises the U.S. Pats. to H. B. Lee, No. 1,645,601 and H. D. Baumann, No. 3,485,474.

The present invention differs over the above references in that a cylindrical double acting ram surrounds a plurality of orifice plates and chambers in a housing. A conical member is mounted on one end of the cylindrical ram and movement of the ram positions the conical member to control flow through the housing.

An object of the present invention is to provide an apparatus for controlling the flow from a variable pressure source in response to the pressure in the source.

Yet a further object of the present invention is to provide housing means with an inlet and outlet for receiving flow from a source and for discharging flow from the housing. Flow constrictor means comprising a plurality of spaced orifice plates mounted in the housing define chambers therebetween for receiving flow from the source into the housing, double acting ram means is movably and sealably mounted in said housing and supports a single conical member thereon for movement into and out of the orifice plates and chambers for controlling the flow area and flow restriction of the flow from the source as it passes through the housing.

Yet a further object of the present invention is to provide housing means with an inlet and outlet for receiving flow from a source and for discharging flow from the housing, flow constrictor means comprising a plurality of spaced orifice plates mounted in the housing define chambers therebetween for receiving flow from the source into the housing, double acting ram means is movably and sealably mounted in said housing and supports a single conical member thereon for movement into and out of the orifice plates and chambers for controlling the flow area and flow restriction of the flow from the source as it passes through the housing, said flow constrictor means including seat means whereby the conical member may be seated to close off flow through the housing to function as a blowout preventor.

Other objects and advantages of the present invention will become apparent from a description of the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating a form of the present invention and a form of the operating means for actuation of the device;

FIG. 2 is a sectional view illustrating in greater detail the structural details of the present invention;

FIG. 3 is a sectional view on the line 3—3 of FIG. 2;

and

FIG. 4 is a schematic illustration diagrammatically illustrating various geometrical parameters for determining the flow area of any orifice or chamber within the housing of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will be described in detail in connection with its use in the drilling of wells such as oil and gas wells by rotary drilling tools well known in the art, however, such description is for purposes of illustration only, as the present invention may be employed to dynamic fluid flow control in other systems.

In the course of drilling oil and gas wells by the rotary method it is desirable to prevent uncontrolled, premature production of formation fluid.

To aid in overcoming such undesired occurrence a drilling fluid is circulated downwardly through the drill string and discharged out the drill bit at the lower end of the drill string and then circulated back up around the drill string in the well bore annulus to the earth's surface. Such circulation is continued throughout the drilling operation and accomplishes a number of desirable functions within the well bore one of which is to provide a fluid of sufficient density to create a hydrostatic head in excess of various formation pressures that may be encountered during the drilling operation.

In some situations formations are encountered while drilling that have formation pressures in excess of the circulating fluid hydrostatic head. It is desirable to correct such situation to prevent what is normally termed a "blowout" — this is, the circulating fluid and excess formation pressure may be discharged from the well which, under some circumstances can cause complete loss of the well being drilled.

The present invention provides a method and arrangement for maintaining the well bore pressure in the annulus within a predetermined range, or to maintain a desired back pressure on the well bore annulus so that the static head of the circulating drilling fluid will always be greater than that of any formation which may be encountered to inhibit blowouts.

This invention may also function as a blowout preventor to completely close in the well bore annulus and close off discharge of the circulating fluid to aid in preventing uncontrolled or undesirable fluid discharge rates of the circulating fluid from the well bore annulus.

Some drilling fluids employed have abrasive characteristics which may cause substantial erosion on some types of choke devices employed, and the present invention is constructed and arranged to accomplish its function with a minimum wear on the components from the circulation of abrasive drilling fluids.

Referring first of all to FIG. 1, the present invention is referred to generally by the numeral 15 and includes housing means 16 in which the flow constrictor means is referred to generally at 20 in FIG. 2. A control arrangement referred to generally at 30 is responsive to the flow into the housing at inlet 31 for operating the flow constrictor means 20 in response to the pressure from the source as measured at inlet 31 to housing 16. The inlet 31 may be provided with suitable threads or the like for connecting with the conduit 41 which communicates pressure from the source to the inlet 31 of the housing 16. The housing 16 also includes outlet 33 for discharge of the fluid flow therethrough.
Suitable means such as a pressure transducer referred to generally at 40 is provided in the conduit 41 which connects with the inlet 31 of housing 16 for conducting variable fluid pressure from a source which for purposes of illustration is the discharge from the well bore annulus. The transducer 40 functions as will be described in greater detail to actuate valve means generally referred to at 45 so that power may be supplied to a suitable motor means (not shown) for actuation of the hydraulic pump 50 for supplying hydraulic fluid to either the hose 51 or the hose 52 for purposes as will be described. When hydraulic pressure is supplied by the pump means 50 through the hydraulic conduit 51 for example, hydraulic fluid from the conduit 52 is discharged back into a hydraulic sump referred to by the letter S in a manner as will be described.

The housing 16 is preferably of a cylindrical configuration and may comprise any suitable number of cylindrical components 60 and 61 which may be threadedly connected together as illustrated at 62. Suitable seal means 63 are provided between the threads 62 to provide a seal between the portions 60 and 61 of the housing 16.

The flow constritor means 20 is better shown in FIG. 2 and includes a plurality of orifice plates 80, 81 and 82 which are maintained in spaced relation by the spacers 83, 84 and 85. The orifice plates 80, 81 and 82 as well as the spacers 83, 84 and 85 are carried within the cylindrical member 90 mounted in housing 16 in any suitable fashion. The orifice plate 82 may be threadedly secured in the end of the cylindrical member 90 as shown in FIG. 2 of the drawings. The orifice plates 80, 81 and 82 each have central axially aligned openings 80a, 81a and 82a.

The cylindrical member 90 is of substantially smaller diameter than the cylindrical members 60 and 61 as shown in FIG. 2 and is coaxial therewith and with inlet 31 in housing 16. The annular space between cylindrical member 90 and housing portion 61 defines a cylindrical chamber 100 for accommodating movement of hollow cylindrical ram 95 as will be described. The cylindrical ram 95 surrounds cylindrical portion 90 and is provided with a flange 96 adjacent one end having an annular seal 97 thereon for slidably and sealably engaging the inner periphery 98 of the housing 16 when the cylindrical ram 95 moves in chamber 100 as will be described. The hollow cylindrical ram 95 moves on cylindrical member 90 and the seal means 103, 104 and 116 inhibit leakage of fluid from cylindrical chamber portion 100, as well as preventing commingling of operating fluid for the constractor means 20 and the fluid from the source passing through housing 16 and constractor means 20.

The cylindrical portion or chamber 100 of the housing 16 is defined by one end wall 101 of the housing 16 and the annular member 102 which is threadedly engaged adjacent the end of the cylindrical portion 61 of housing 16 as shown in FIG. 2. Suitable seal means 103 and 104 are provided on each annular edge of the annular member 102 so as to seal respectively with the outer periphery 105 of ram 95 and the inner periphery 98 of cylindrical portion 61 of housing 16, as previously noted.

Fittings 51a and 52a are provided in openings 110 and 111 of cylindrical section 61 for engaging with hydraulic hoses 51 and 52 so that hydraulic fluid may be applied on either side of the ram 95, thus making it double acting in function. The flange 96 with seal 97 thereon as well as annular member 102 provide a closed chamber 100 within which the operating hydraulic fluid to operate ram 95 may be discharged, but prevents commingling of such hydraulic fluid with the fluid passing through the housing 16 which is being controlled, as noted previously.

The end 113 of ram 95 is provided with discharge outlets 114 that communicate with the chamber 115 that surrounds an extension on the end of the conical member 120 which extension mounts the conical member 120 on the end of ram 95 in any suitable manner as shown in FIG. 2 of the drawings.

The conical member 120 faces upstream within the orifice plates 80, 81 and 82 and chambers 125, 126 and 127 formed therebetween toward the inlet 31 of housing 16. The ram 95 is provided with an annular shoulder 95a spaced from flange 96, which shoulder engages annular member 102 and limits movement of ram 95 in chamber 100. When the ram is in the position as illustrated in FIG. 2 it is seated on the orifice plate 82 and closes off flow through the housing. It will be noted that the orifice plate 82 is provided with a seat 82a for receiving the seat 120a formed on the extension at the end of conical member 120, and it will be further noted that the orifice plate 82 is the furthest orifice plate from the inlet 31 of the housing 16.

The arrangement of the orifice plates 80, 81 and 82 with the spacers 83, 84 and 85 therewith provide turbulence flow chambers 125, 126 and 127. It will be noted that each turbulence chamber is tapered as shown. Of course, it can be appreciated that any number of orifice plates and any number of spacers may be provided to form or define any number of chambers as may be desired. In such event, the length of the conical member 120 will be adjusted accordingly so that when it is in fully closed position as shown in FIG. 2 of the drawings the apex 130 thereof will be at the left end of chamber 125 adjacent inlet 31 as shown in FIGS. 2 and 4 of the drawings.

In the operation of the present invention, the transducer 40 detects the pressure of the fluid from the source conducted to the inlet 31 of housing 16 and to be controlled therein. Depending upon the type of transducer, a signal will be transmitted, either electrically or hydraulically, or pneumatically through conduit 40 to actuate valve means represented generally at 45. The valve means 45 may be a spring loaded type so that it can be preset to maintain any desired flow control conditions in housing 16. For example, valve means 45 may be set so that should the pressure into the inlet 31 of housing 16 exceed a predetermined amount, such valve means will function to supply power from any suitable source such as from an air source on the drilling rig through the conduit 140 to operate an air motor which in turn operates the pump 50. The valve means 45 will further function so as to communicate conduit 51 with the discharge side of the pump means 50 whereby fluid may be discharged into the chamber 100 to move the ram 95 towards the left as illustrated in FIG. 2 of the drawings to cause the conical member to seat and close off flow through the device. In such event, undesired or unwanted discharge of fluid from the well bore annulus when it exceeds a predetermined pressure may be accomplished.

Similarly, the valve means 45 may be set so that, depending upon the pressure from the variable source as
measured at the inlet by the transducer 40, such valve means function to move the ram 95 to the right or to the left by supplying fluid through either the hydraulic hose 51 or hydraulic hose 52. It can be appreciated that when the hydraulic ram is moved in one direction by hydraulic fluid acting on one side thereof, the other hose acts as a discharge to discharge the hydraulic fluid from the other side of the ram back to the pump S with which the pump 50 communicates by means of its intake. The valve means 45 functions to connect the discharge of pump means 50 with either hose 51 or 52, depending upon the signal received from transducer 40.

The positioning of the conical member 120 relative to the orifice plates 80, 81, and 82 and chambers 125, 126 and 127 will thus depend upon the pressure of the source being controlled. In some situations the conical member will be moved only partially in one or more of the orifice plates, and under some circumstances, it can be appreciated that the ram 95 will be moved to the right (as viewed in FIG. 2) when the pressure measured by the transducer 40 at the inlet 31 of housing 16 indicates that such should occur so as to provide less restriction to fluid flow through the choke device.

Thus, the flow constriction means 20 functions as a throttling valve arrangement to control the discharge of the fluid being controlled by the present invention from the housing 16 and through discharge conduit 150. It will be noted that the closure member which is in the form of the conical member 120 is configured so as to provide a minimum of erosion thereto while accomplishing its function.

It will be noted that the spacers 83, 84 and 85 form a conically diverging passage from the inlet 31 to the valve seat 82a' so as to reduce pressure of the fluid by volumetric expansion. The cross sectional flow area through a portion of the choke passage is determined by the dimensions of the cone member 120 and the actual position of such cone relative to any one or more of the orifice plates in the flow constriction means 20.

The apex 130 of conical member 120 is at beginning of the first chamber 125 when the member 120 is seated as shown in FIG. 2.

As drilling fluid enters the choke device of the present invention, it undergoes the desired pressure and flow control as the valve means 45 is operated by the transducer 40, and depending upon the conditions desired within the control device. Of course, such conditions are determined and the valve means then set accordingly so as to react properly to the transducer 40 to position the cone member 120 relative to the chambers 125, 126 and 127 to accomplish the desired pressure and flow restriction upon the fluid pressure from the source. In some situations, it may be desirable to manually control the present invention and in such event means 160 may be employed to operate valve means 45 so that the motor means and pump means 50 is actuated as desired to control the position of ram 95.

The housing 16 may be supported on any suitable frame as indicated at 16a in FIG. 1.

FIG. 4 illustrates the geometric parameters associated with the specific embodiment herein described. By selection of components of different dimensions, including the cone member 120, orifice plates 81, 82 and 83 as well as spacers 83, 84 and 85, different design requirements may be obtained.

Of course, in addition to the aforementioned components, dimensional flow relationship will vary in accordance with the position of the cone member 120 relative to the various orifice plates and chambers. The flow area relationships are indicated in the following equations:

\[
A_c = \pi[(R_0 + L_0 \tan \theta)^2 - \pi(\frac{L_c - D}{\tan \phi})^2]
\]

\[
A_r = \pi[(R_0 + L_0 \tan \theta - \tan \phi)^2 - \pi(\frac{L_n - D}{\tan \phi})^2]
\]

In the above equations the following definitions apply:

- \(A_c\) is the flow area of any chamber under consideration, or being calculated;
- \(R_0\) is the radius of the housing inlet;
- \(L_c\) is the distance from the beginning of the first chamber adjacent the inlet of said housing to the mid-point of the chamber whose flow area relationship is being calculated;
- \(\phi\) is the angle of the taper on the conical member;
- \(\theta\) is the angle of the taper of the turbulence chambers;
- \(D\) is the distance from the beginning of the first chamber at the inlet of the housing to the apex of the conical member;
- \(A_t\) is the flow area of the orifice opening whose flow area is being calculated;
- \(L_n\) is the distance from the beginning of the first chamber at the inlet of housing 16 to the midpoint of the orifice plate whose flow area is being calculated;
- \(T_n\) is the thickness of the orifice plate member whose flow area is being calculated.

Theoretical flow conditions on the other hand will be in accordance with the following equations:

\[
V_2 = V_1 \frac{A_1}{A_2} \frac{T_1}{T_2} \frac{P_1}{P_2} \frac{G}{V_1}
\]

\[
H_t = \left[(\frac{1}{0.95}) - 1\right] \left(V_2^2 - 2G\right)
\]

\[
H_c = \left(V_1 - V_2\right)^2 \frac{2G}{V_1}
\]

Wherein \(V\) is flow velocity, 0.95 is the coefficient of orifice plate taken as 0.95, \(P\) is static pressure, \(Q\) is flow rate, \(\rho\) is fluid density, \(H_t\) is head loss at the orifice opening, \(H_c\) is head loss at any turbulence chamber and \(T_1\) and \(T_2\) is the thickness of orifice plates designated in FIG. 4 as 1 & 2 inscribed in a circle.

The foregoing construction enables dimensional selection of components by computer programming and in order to meet any design flow conditions desired. The orifice plates and chambers assist in functioning to cause stepwise pressure and velocity reduction as desired, and create turbulence in chambers to dissipate energy, thereby reducing wear and erosion thereby minimizing stress failure on the components of the structure. The conical member further reduces erosion by its configuration and absorbing the impact of the abrasive particles in the drilling fluid and also provides a method of controlling fluid flow by varying the flow area along the choke passage through the flow constriction means 20 within the housing 16.

When the fluid is discharged from openings 114, it passes into the chamber formed by cylindrical portion 60 of housing 16 and is then discharged through outlet 33 of housing 16.

Thus, the constriction means 20, by positioning conical member 120 relative to one or more of the orifice plates and chambers aids in reducing pressure and velocity of the pressure from the variable source.
As a result of the foregoing arrangement the fluid from the source, such as drilling fluid entering the choke device of the present invention undergoes a graduated, controlled reduction of both pressure and velocity between the inlet 31 and outlet chamber formed in cylindrical portion 60. The arrangement of the present invention is such that there are no major areas or wear surfaces that can receive severe stress reversals or destructive direct impact of high velocity abrasive particles.

A pressure transducer may be applied to the inlet of the mud supply at the drilling string and a conduit such as the conduit 40' then connected from such transducer to the valve means 45 so that the present invention is controlled by the inlet pressure to the drill string rather than the outlet pressure.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape, and materials as well as in the details of the illustrated construction may be made without departing from the spirit of the invention.

1 claim:

1. An apparatus for controlling fluid flow from a source comprising:
   a. housing means having an inlet for receiving flow from the source and an outlet for discharging flow from the housing;
   b. flow constrictor means mounted within said housing and including;
      1. a plurality of spaced orifice plates mounted in said housing and providing chambers therebetween for receiving flow from the source into said housing;
      2. double acting cylindrical ram means surrounding said orifice plates and chambers and movably and sealably mounted in said housing;
      3. a single conical member mounted on said ram means at one end thereof and movable into and out of said spaced orifice plates and chambers;
      4. said orifice plate which is spaced furthest from the apex of said conical member forming a seat for receiving said conical member to close off flow through said housing; and
   c. means responsive to the fluid pressure from the source for moving said flow constrictor means to position said conical member relative to said orifice plates and chambers to thereby control flow from the source through said housing.

2. The invention of claim 1 wherein said responsive means for operating said flow constrictor means comprises:
   a. transducer means for determining the pressure from the source;
   b. pump means for pumping hydraulic fluid to act on said ram means;
   c. motor means for operating said pump means;
   d. valve means operable by said transducer means for actuating said motor means; and
   e. valve means operable by said transducer means for controlling the flow of the hydraulic fluid to either side of said ram means to position said conical member relative to said orifice plates and chambers to control the flow from the source through said housing in response to the source pressure.

3. The invention of claim 1 wherein the flow area relationship within said housing is defined as follows:

   \[ A_c = \pi [(Ro + L \cdot \tan \theta)^2 - \pi [(L - D) \cdot \tan \phi]^2] \]

   \[ A_t = \pi [(Ro + L \cdot \tan \theta - \sec \theta)^2 - \pi [(L - D) \cdot \tan \phi]^2] \]

   In the above equations the following definitions apply:
   \( A_c \) is the flow area of any chamber under consideration, or being calculated;
   \( Ro \) is the radius of the housing inlet;
   \( Lc \) is the distance from the beginning of the first chamber adjacent the inlet of said housing to the midpoint of the chamber whose flow area relationship is being calculated;
   \( \phi \) is the angle of the taper on the conical member;
   \( \theta \) is the angle of the taper of the turbulence chambers;
   \( D \) is the distance from the beginning of the first chamber at the inlet of the housing to the apex of the conical member;
   \( At \) is the flow area of the orifice opening whose flow area is being calculated;
   \( Ln \) is the distance from the beginning of the first chamber at the inlet of housing 16 to the midpoint of the orifice plate whose flow area is being calculated;
   \( Tn \) is the thickness of the orifice plate member whose flow area is being calculated.

* * * * *
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,791,621 Dated February 12, 1974

Inventor(s) Asadollah Hayatdavoudi

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

Col. 7, line 45, Claim 1, "flow constrictor" should be -- ram --.
Col. 5, line 30, "120a" should be -120-
Col. 6, line 44, "I2" should be -T2-

Signed and sealed this 17th day of September 1974.

(SEAL)
Attest:

McCoy M. Gibson Jr. C. Marshall Dann
Attesting Officer Commissioner of Patents