The disclosure concerns a well blowout preventer assembly incorporating a packer constricting actuator which forms with the housing at least three pressure receiving chambers, a first of which receives control fluid pressure acting to urge the actuator downwardly for relieving packer constriction; a second to receive control fluid pressure acting to urge the actuator upwardly for constricting the packer; and a third to receive controllable balancing pressure acting to urge the actuator upwardly in at least partly counter-balancing relation to the opposite effect of well fluid such as drilling mud, the static pressure of which (especially in subsea oil well drilling operations) acts via the packer to urge the actuator downwardly.
WELL PRESSURE COMPENSATED WELL BLOWOUT PREVENTER

BACKGROUND OF THE INVENTION

This invention relates generally to subsea oil well drilling operations, and more particularly concerns apparatus and methods for controlling blowout prevention equipment in such environments.

Within recent years the increased drilling of off-shore wells has necessitated the development of specialized well head equipment adapted to be installed at subsea locations. Such equipment has included the use of well blowout preventers of the type wherein a packer annulus is adapted to be radially constricted to close on well drill pipe in response to upward stroking of an actuator to which fluid pressure is supplied. In this regard, such preventers incorporate what are known as opening and closing pressure chambers to which fluid is alternately supplied under pressure to effect opening and closing of the preventer packer. See U.S. Pat. No. 2,609,836.

It has been found that the minimum difference between fluid pressures applied to the opening and closing chambers necessary to maintain the packoff of the well increases with the density and the height of the column of drilling mud in the riser, above the packer, whereby the deeper the preventer installation below the ocean surface, the higher the differential pressure closed fluid to a preventer. It had been hoped that the static pressure of control fluid in a supply riser or lines running from the surface to the opening and closing chambers would sufficiently compensate for the tendency of the drilling mud column to resist closing of the packer; however, the difference in densities of the control fluid and drilling mud is a factor that is difficult to overcome. Also, the adverse effect of the drilling mud column increasing as the diameter of the drill pipe decreases, and also as the density of the mud increases. These difficulties also are intensified in the absence of added static control pressure application to the opening and closing chambers.

Thought has been given to balancing the actuator piston surface areas exposed to packer closing and opening pressures, as by enlarging the inner diameter of the closing chamber; however, this would raise the additional problem of affording a greater area of the actuator underside to receive application of pressure of well fluid (below the packer) tending to close the packer, and producing excessive stresses in the packing element, causing a reduced operating life of the element.

BRIEF SUMMARY OF THE INVENTION

It is a major object of the invention to provide a blowout preventer assembly of such construction and mode of operation as will overcome the problems and difficulties referred to above, as well as others that may be encountered in practice. Basically, the assembly incorporates a packer constricting actuator which forms with the housing at least three pressure receiving chambers, a first of which receives control fluid pressure acting to urge the actuator downwardly for relieving packer constriction; a second to receive control fluid pressure acting to urge the actuator upwardly for constricting the packer; and a third to receive controllable balancing pressure acting to urge the actuator upwardly in at least partly counter-balancing relation to the opposite effect of well fluid such as drilling mud, the static pressure of which, acts via the packer to urge the actuator downwardly. In this regard, the third chamber may be so located as to permit enlarging of the first and second chamber diameter and further to maintain these two to be approximately equal (so as to produce a balanced pressure application on the actuator tending to close the packer) without exposing such greater area of the actuator underside to the pressure of well fluid (below the packer) as could cause damaging stresses in the packer element and render opening of the packer difficult.

Additional objects of the invention include the provision of a preventer assembly of improved construction to yield the advantages described; and the provision of inter-related controls for pressure delivery to the first, second and third chambers as described.

These and other objects and advantages of the invention, as well as the details of an illustrative embodiment, will be more fully understood from the following detailed description of the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical elevation, taken in section, showing a preventer assembly embodying the invention, in open condition;

FIG. 2 is a view like FIG. 1, but showing the preventer in closed or actuated condition; and

FIG. 3 is an elevation showing the preventer of the invention installed in a subsea well head assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning to FIG. 2, the control head or preventer assembly, generally indicated at 10, includes a body member 11, having concentric bores 12, 13 and 14, which are of progressively increased diameters. Cap 16 is releasably held to the body member by screw thread connection 17 in such a position that the face 19 of cap flange 20 engages the upper end 21 of the body member 11, the cap and body member being packed off at 22. Cap 16 has a bore 23 which is of the same diameter and is concentric with bore body bore 12. Sunken in the upper face of cap 16 are bolt holes 24 for the attachment of equipment theretofore. The annular groove 25, in that upper face, is adapted to receive a sealing ring for sealing engagement with said equipment.

The neck 26 of body member 11 has an attachment flange 27 whereby connection is made through bolts 28 to the flange 29 or any other suitable fitting.

Cap 16 has an internal annular flange 35 which defines the downward continuation of bore 23, and a peripheral flange 36 which defines bore 37, said bore 37 being concentric with all the body members bored identified above.

The body 11 has an annular, upstanding flange 38 which engages the actuator actuating member 39 at 40 to limit the extent of downward movement of said member. The actuator 39 has a piston portion 41, having piston-fit in bore 14, and piston portion 42 which has piston-fit in bore 13. The actuator is extended upwardly at 43, extension 43 having piston fit in the cap-flange bore 37. Sealing rings 44, 45 and 46 are provided between piston portions 40, 41 and 43, respectively, and the respective cylinder defining walls which receive those portions.

Piston 41 divides body bore 14 into upper (first) and lower(second) cylinders or pressure chambers 47 and 48, ports 49 and 50 opening, respectively, from those chambers. External pipes 51 and 52 open to ports 49 and 50, respectively. Note that the outer diameters (14) of chambers 47 and 48 are equal, and the inner diameters (13) and 37 of these chambers are equal, for balancing purposes.

The actuator 39 has a downwardly and inwardly taping conical bore 53, and the actuator portion 43 which defines this bore may be considered broadly as an internal, conical wedge, or as a packer-constricting element.

Packer P includes a massive annulus or sleeve 55 of plastic and, preferably, resilient material such as rubber or Neoprene. In most instances, it is intended that a single packer be adapted for repeated opening and closing operations, and therefore it is preferable that it have relatively high resilient characteristics, so it may be selfrestoring to open position when the constricting force is removed. From this point on in the description, it will be assumed that the packer has such resilient characteristics, but this assumption is not considered as limiting on my broader claims. It has been found that rubber having a durometer hardness of about 75 is suitable for general use in my packer but, again, this specification of relative hardness is not to be considered as limiting. The packer
is shown as an unsplit, continuous annulus, but it will be understood that the disclosure is not limited to a packer wherein there is no split, so long as there is no angularly extending gap interrupting the continuity of the packer at times when it is radially contracted into sealing engagement with members positioned within its bore.

Included in the makeup of the packer is a series of rigid, rubber-flow-control elements 56. These elements may take different forms and still lie within the scope of my broader claims, but I will first describe the preferred form of elements which has individual features of advantage. These rigid control elements are individually movable bodily with the rubber in its movement of radial contraction and expansion and also, to a limited extent, moveable individually with respect to the rubber as will later appear. Taken together, the rigid control elements may be considered as a radially expansive and contractible armature embedded and bonded within annulus 55.

Molded annulus 55 has an outer conical face 57 which is complementary to actuator bore 53, and a bore 58 which has a central, substantially cylindrical portion 59 and oppositely inclining upper and lower portions 60 and 61, respectively; the outward flare, in each case being toward the associated end of the annulus.

It will be seen that each element 56 comprises top and bottom plates 63 and 64, respectively, rigidly connected by verticalrib 65, the outer faces 66 of the plates and the outer face 67 of the rib having substantially the same degree of taper as bore 53 and annulus face 57. Or plates 63, 64 may be considered as transverse flanges on rib 65. Elements 56, which may be of steel, bronze, or any other suitable rigid material, are preferably positioned in the rubber at the time of molding and, preferably, the rubber and the elements are bonded together by the use of suitable adhesive during the molding process. The plates of the control elements are sectorial in shape, as viewed in plan, and are arranged in a circular series, with spaces left between the opposing side edges of the plates, both top and bottom. The plates are so sized that the two opposed side edges of adjacent elements are spaced apart, it following that as the elements move radially inward, the spaces between these, will diminish to form a line contact from top to bottom of the plates. This will prevent the rubber which will flow during the contraction of the annulus from being pinched off at the radially inward ends of the plates.

The annulus 55 is molded so its outer annular portion 72 projects radially outward beyond the outer faces 66 of the plates, it following that these metallic faces do not engage the wall of actuator bore 53. For purposes of later description, I will consider annular portion 72 as being that portion which extends radially from face 57 to the outer faces 67 of the plates 63.

The packer is lowered, while cap 16 is detached, into the position of FIG. 1, the annulus 55 nicely fitting the upper portion of bore 53 without requiring appreciably radial constriction of the annulus. For positively limiting the downward movement of the annulus, a stop is provided in the form of a tube 74 which is retained in housing bore 15. The upper end of the tube provides the packer stop. The bore 75 of this tube is of the same diameter as bores 12 and 23, and the tube is annularly spaced from both piston portion 42 and the lower end of actuator wedge portion 43. Ports 76 open from bore 75 to chamber 77, which latter is annularly defined by the tube and the sleeve 80, while it is retained endwise by body wall 78 and the lower end of the packer.

When cap 16 is subsequently secured in place, its horizontal under-surface 79 provides a stop for limiting upward movement of the packer, the upper plates 63 of control elements 56 sliding over this surface as the packer is radially constricted or expanded. Tube end and cap surface 79 thus form vertically spaced stops which prevent appreciable vertical movement of the packer with relation to the body member 11.

It will be seen that the radial constriction of the packer is accomplished by virtue of relative vertical movement between the packer and the actuator. While the illustrated embodiments show this relative movement as brought about by holding the packer against vertical movement with respect to the body member and then moving the actuator vertically with respect to the housing and packer, it will be understood that arrangement and operation may be reversed.

The sleeve 80 and body 11, together with actuator piston portion 42 form a third chamber 82 to receive control pressure fluid (as via porting 83 and pipe 84) acting to urge the actuator upwardly in at least partly counterbalancing relation to downward force exertion on the body member 11. In particular, such downward force is to be so counteracted usually may typically result from the static pressure p1 of a column of drilling mud in the annulus 85 outside the drill pipe 86, such mud circulating downwardly in that pipe to the bit, and rising in the annulus. FIG. 3 shows the riser 87 within which the mud flows to the surface. The mud pressure is applied to the packer P tendency to expand it, and downward thrust is thereby transferred to the actuator 39 across, enlarged tapered surfaces 57 and 53, when the packer is closing in the well.

At the same time, well pressure, p1, as for example in the annulus 185 below the packer, is communicated via openings 76 in tube 74 to the chamber 77 and to the underside of actuator 39 within the diametral dimension defined by the inner diameter 89 of actuator piston portion 42. A seal 88 packs off between sleeve 80 and piston portion 42 to prevent application of well pressure over a larger area of the underside of the actuator.

It should be noted that the third chamber 82 is also located that the first and second chambers 27 and 48 may have other diameters which are approximately equal, affording enlarged piston surface area beneath piston portion 41 of the actuator whereby greater upward thrust may be communicated from fluid in chamber 48 (closing pressure p3) to the actuator for closing the packer against resistance associated with the static mud pressure p1. This is achieved without enlarging the underside area of the actuator subjected to well fluid pressure and in fact the pressure p1 in chamber 27 may be independently controlled to levels greater than or less than the well fluid pressure p2, giving an additional degree of actuator control not previously known, but of great and surprising advantage.

Summarizing, the forces that act downwardly on the actuator 39 are derived from and proportional to:

\[ p_2 = (\text{Mud static pressure}) \]

\[ p_0 = (\text{Operating fluid pressure applied chamber 47 during opening of the packer}) \]

The forces acting upwardly on the actuator are derived from and proportional to:

\[ p_1 = (\text{Well fluid pressure}) \]

\[ p_1 = (\text{Control fluid pressure applied to chamber 32 to counteract p3}) \]

\[ p_1 = (\text{Operating fluid pressure applied to chamber 48 during closing of the packer}) \]

Referring again to FIG. 1, a gas pressure vessel 90 is shown as communicating with pipes 51 and 52 via a suitable pressure regulator 91 and four way valve 92. In one position of the latter, pressure fluid is delivered to pipe 52, and pressure fluid in pipe 51 is exhausted at 93 to the sea. In the alternate position of the valve 92, pressure fluid is delivered to pipe 51 and fluid in pipe 52 is exhausted to the sea. A suitable electric prime mover 94 controls valve 92 and a suitable control 95 for the regulator may be surface operated to set the pressure applied to pipes 51 and 52. Similarly, pressure may be supplied to pipe 84 via regulator 96 and three way valve 97. Controls for the regulator and valve are indicated at 98 and 97 and may be electrically operated from the surface, to result in selected pressure applications to chamber 82, a cable to the surface being indicated at 199. Control 98 for regulator 96 may be connected via pipe 110 to annulus 85 to be responsive to mud.
pressure near the packer, so as to effect transmission of higher pressure to chamber 82 as the mud pressure increases.

Finally, reference to FIG. 3 shows the preventer assembly 10 connected to a subsea blowout preventer stack 100, including a unit 10 above a series of ram type preventers 101. A riser system 102 extends above the stack 100 and is connected therefor by a well head connector 103. Riser pipe extends to the sea surface, and typically to a drilling barge 104 or other installation. Stack 100 and riser 102 are illustrative only, and may carry the pressure vessel 90 and associated piping and controls referred to above.

We claim:
1. In a well blowout preventer assembly, the combination comprising:
   a. a housing connectible in an underwater stack of well servicing equipment;
   b. an inwardly constrictible packer annulus positioned in the housing to form therewith a vertical passage through which tubular goods may be run in the well;
   c. an annular actuator moveable upwardly in the housing to constrict the annulus for reducing said passage, the packer annulus adapted to receive application of force resulting from exertion of the static pressure of well fluid in said passage, and to transmit said force tending to urge the actuator downwardly;
   d. the actuator and housing forming a first chamber to receive control pressure fluid acting to urge the actuator downwardly for relieving said packer constriction, and a second chamber to receive control pressure fluid acting to urge the actuator upwardly for constricting the packer; and
   e. the actuator and housing forming a third chamber to receive balancing pressure fluid acting to urge the actuator upwardly in at least partly counterbalancing relation to the opposite effect of said static pressure.
2. The combination of claim 1 including means transmitting balancing fluid pressure to said third chamber as a function of said static pressure of well fluid.
3. The combination of claim 1 including said stack of equipment in which said housing is connected beneath the ocean surface level, there being well fluid in a pipe string connected with and extending above said stack and said well fluid exerting said static pressure.
4. The combination of claim 3 wherein said well fluid comprises drilling mud.
5. The combination of claim 1 wherein said first and second chambers are annular and have outer diameters and inner diameters which are approximately equal.
6. The combination of claim 5 including fluid pressure source means in the stack, and means to controllably transmit fluid pressure from said source means to said first, second and third chambers.
7. The combination of claim 1 wherein said third chamber is below the levels of said first and second chambers where the actuator is in down position.
8. The combination of claim 1 including an annular flange integral with the housing and projecting upwardly within the open interior thereof, said actuator includes an annular piston projecting downwardly adjacent to and in concentric relation to said annular flange, and means sealing off between said annular flange and annular piston.
9. The combination of claim 1 wherein the outer diameter of the third chamber is not greater than the inner diameters of the first and second chambers.