United States Patent

Murman et al.

[15] **3,695,349**

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[54] **WELL BLOWOUT PREVENTER CONTROL PRESSURE MODULATOR**

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[21] Appl. No.: **21,130**

[52] **U.S. Cl.** **166/.5,** 251/1, 166/84

[51] **Int. Cl.** **E21b 33/035**

[58] **Field of Search** 166/53, 84, 86, 75, 82; 251/1; 277/28, 34, 103, 73

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[57] **ABSTRACT**

The constriction of a packer or other tool about a pipe string being run in a well is altered in such manner while a pipe joint is passing through the packer as to facilitate rapid running of the string in a well and to reduce wear of the packer.

37 Claims, 12 Drawing Figures

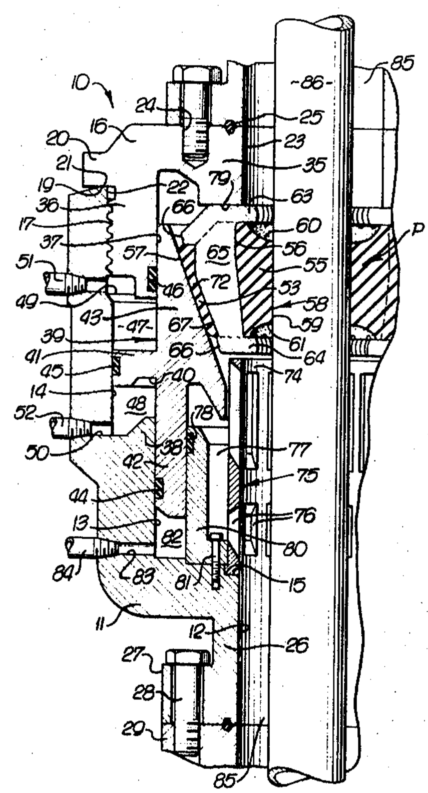

FIG. 1.

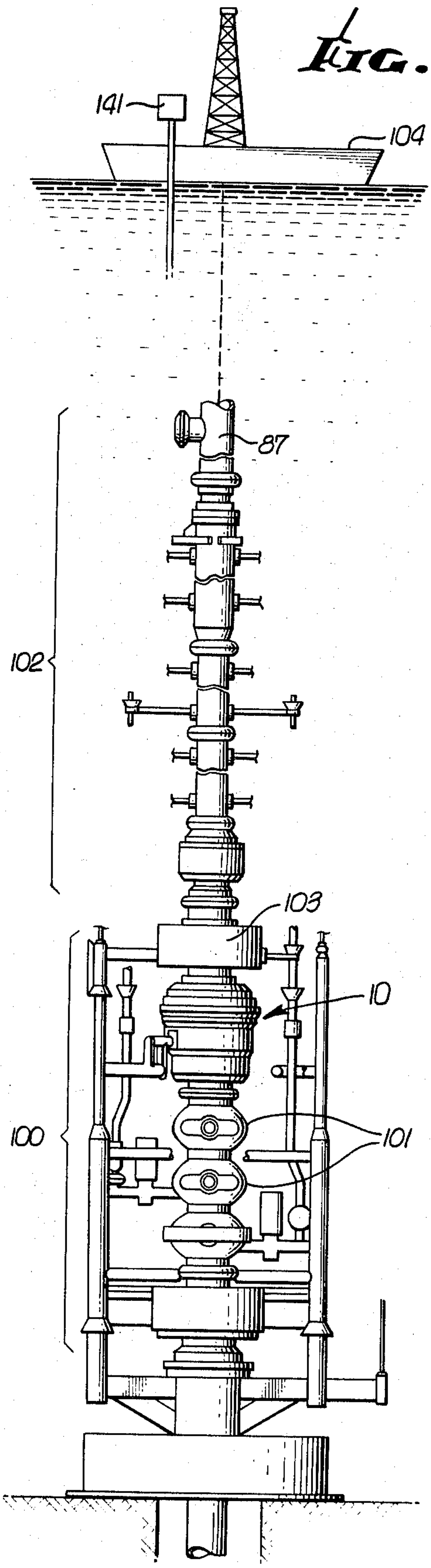

FIG. 2.

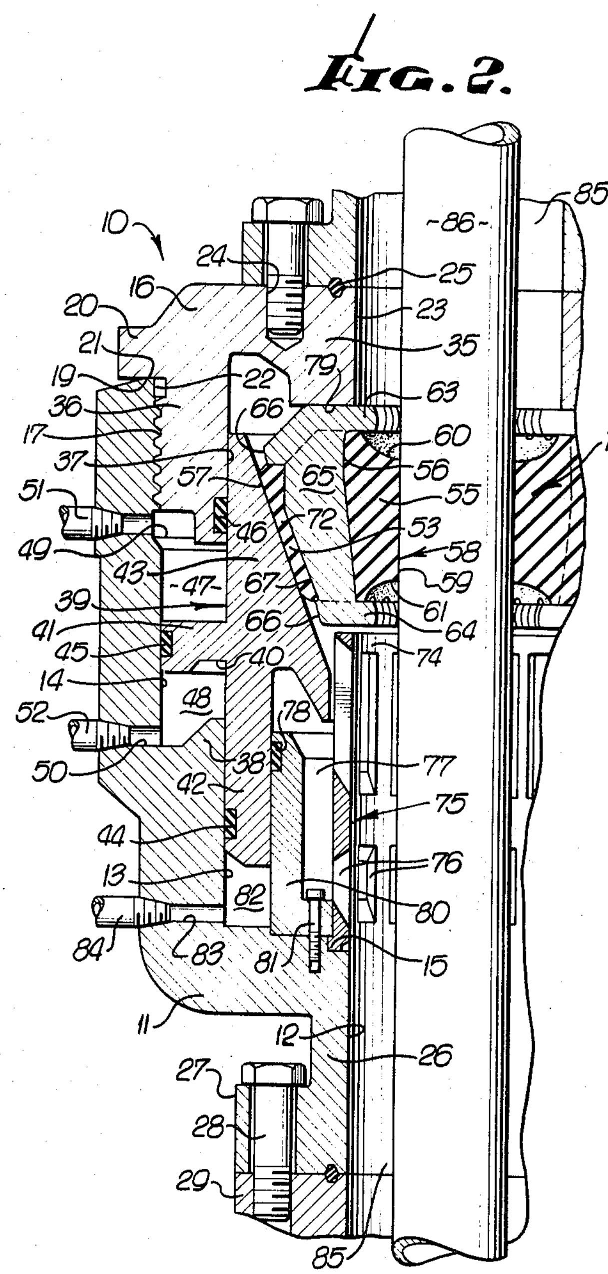

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FIG. 3.

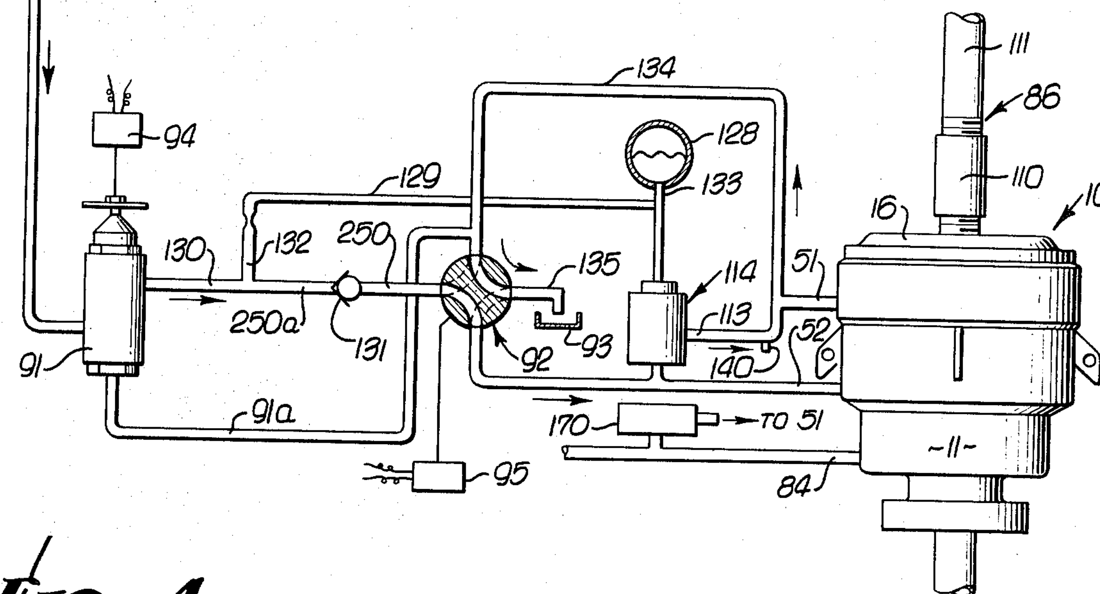

FIG. 4.

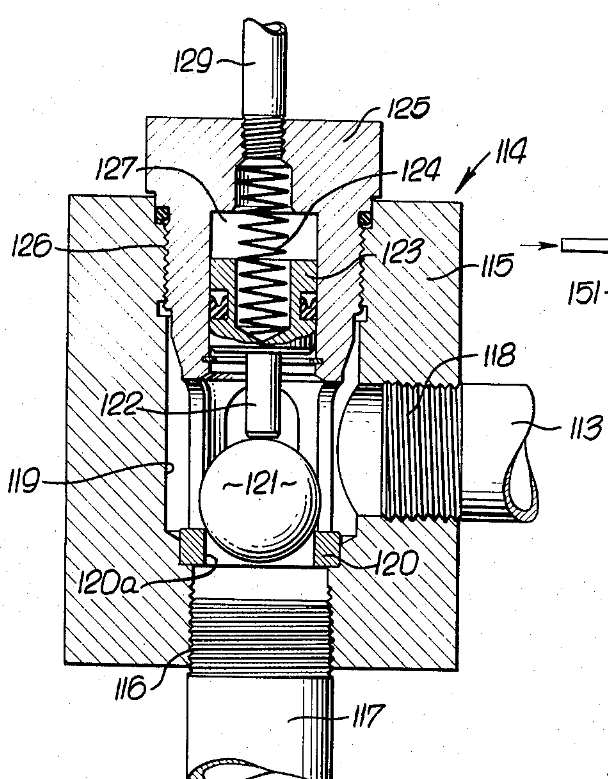

FIG. 5.

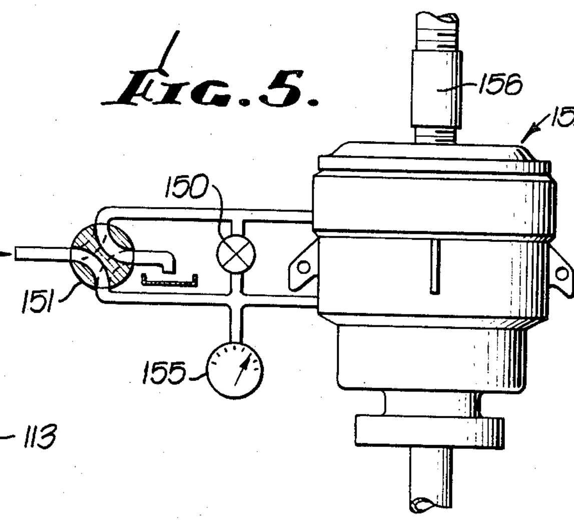

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FIG. 6.

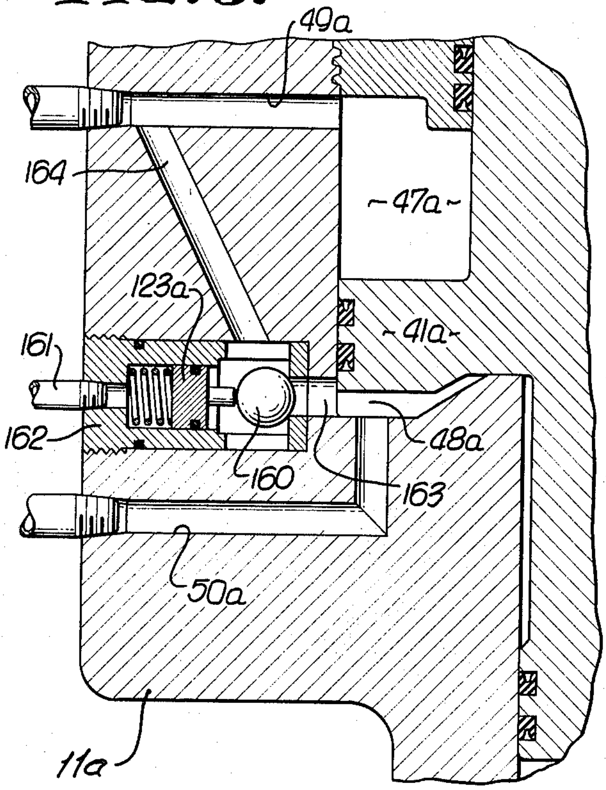

FIG. 8.

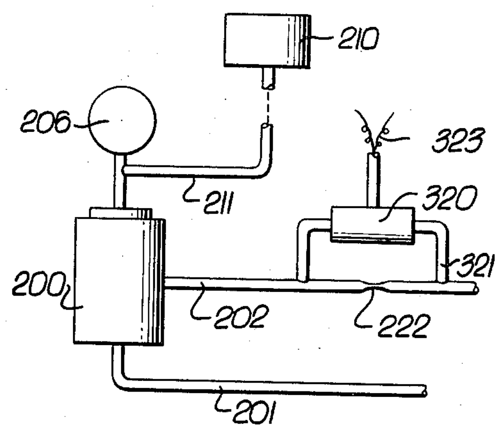

FIG. 9.

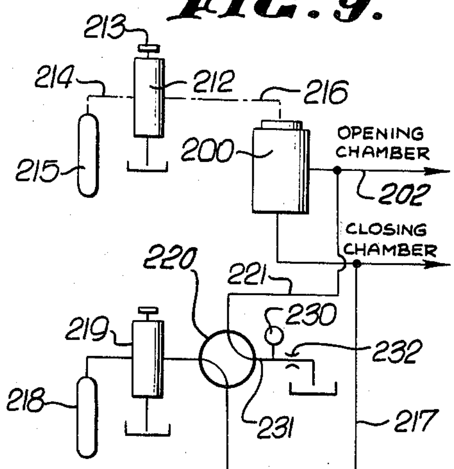

FIG. 7.

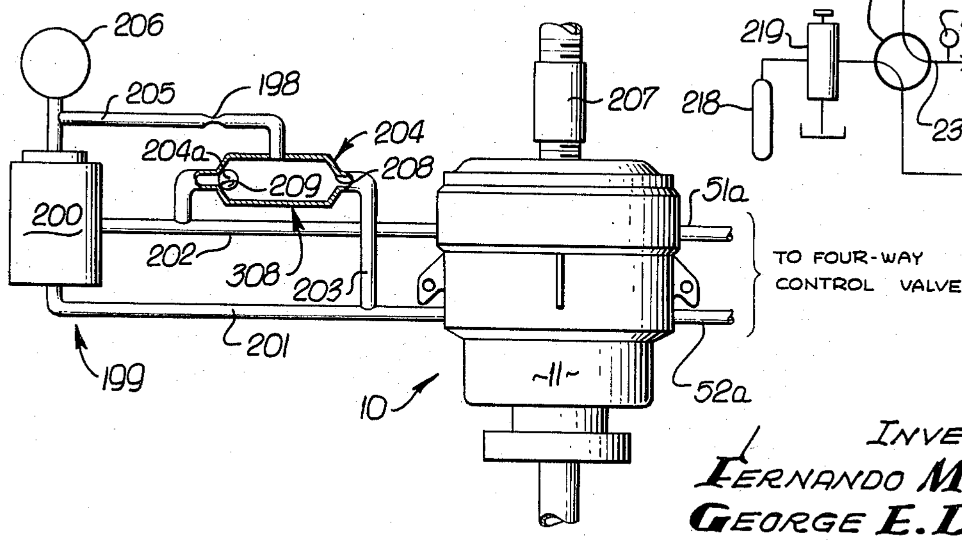

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FIG. 10.

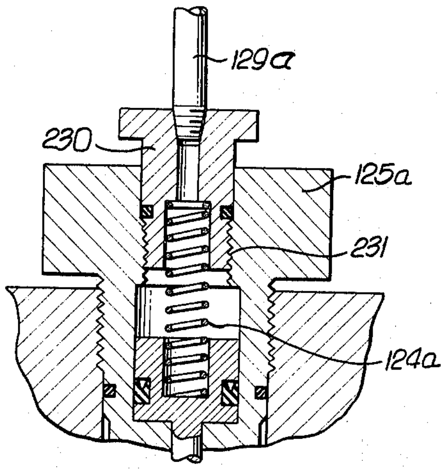


FIG. 11.

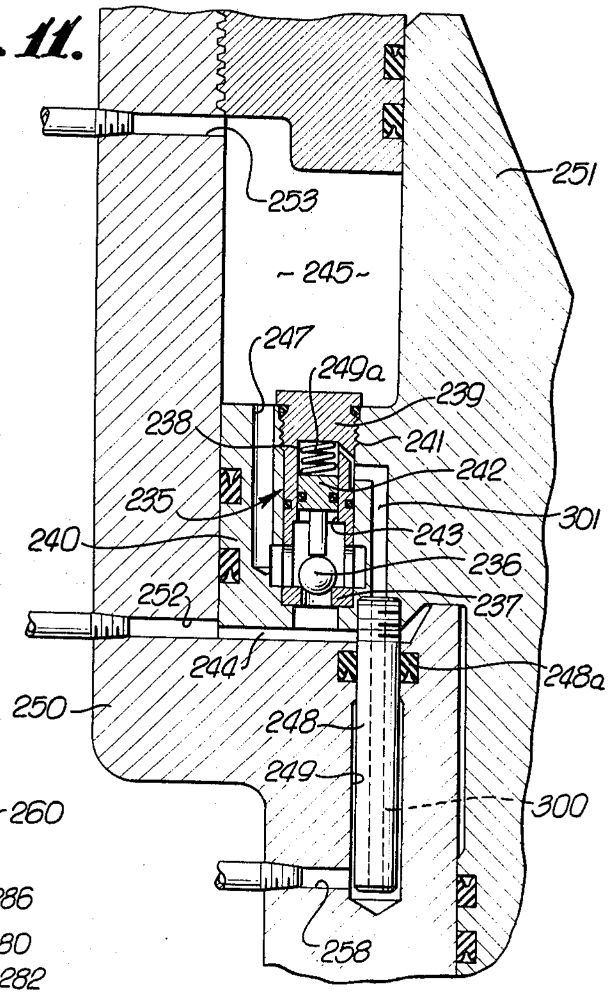
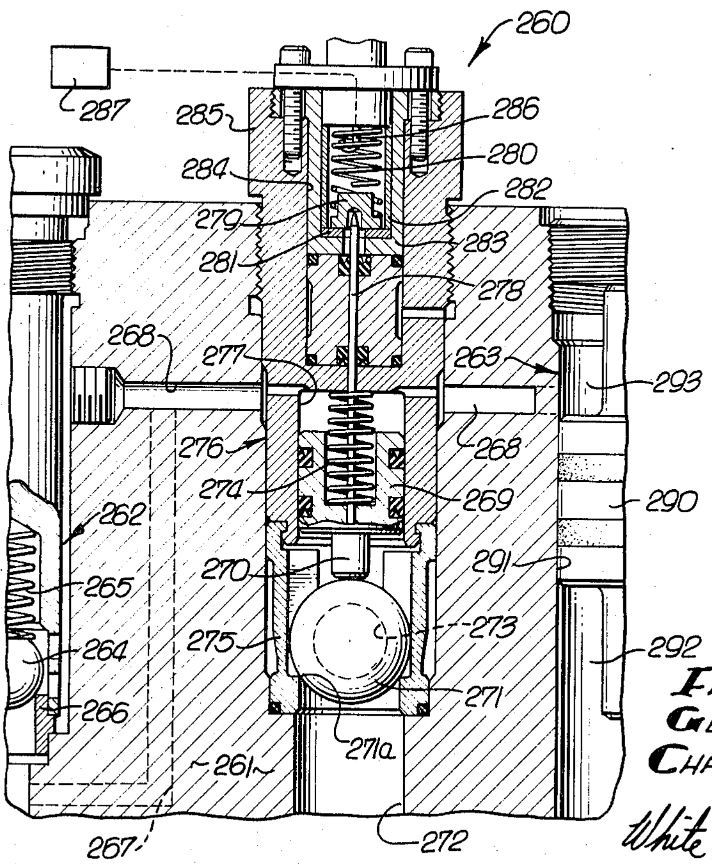


FIG. 12.



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WELL BLOWOUT PREVENTER CONTROL PRESSURE MODULATOR

BACKGROUND OF THE INVENTION

This invention relates generally to the control to tool engagement with vertically movable well strings, and more particularly concerns the reduction of resistance to vertical travel of such strings through packers closed about such strings.

In well drilling operations it is frequently the practice to constrict a packer element, (as for example in a flow-out preventer) about the drill string so as to shut-in the gas pressure in the wall annulus. Such constriction must be maintained as the string is moved vertically in the well, as for example during downward drilling or upward retrieval of the string. Where the string includes enlargements such as tool joints, it is found that excessive time is taken up by forcible pulling or lowering of the joints through the constricted packer element, and also that the latter is subjected to excessive wear, decreasing its useful life. For example, in order to reduce such wear, it is the practice to travel a typical joint through the packer of a Hydril Blow-out Preventer (Model GK-10—5000) at only a few inches per second, whereas the string between successive joints may be traveled at several feet per second through the constricted packer.

The above problem becomes extremely critical in off-shore, sub-sea packer installations where a drill string is suspended from a drilling barge. It is found that wave action induced lifting and lowering of the barge and string may cause a string joint to stroke up and down through a constricted packer at such high speed as to result in undesirably rapid wear or deterioration of the packer rubber, necessitating extremely expensive recovery and replacement of the packer at undesirably "frequent" time intervals.

SUMMARY OF THE INVENTION

It is a major object of the invention to provide apparatus and method for overcoming the above described problems. Basically, the method of the invention is applicable to a system that includes packer means, typically annular, that is laterally constricted to engage a well string being passed longitudinally through the packer, and means including a packer actuator forming a first chamber receiving fluid pressure acting to urge the actuator in a direction to effect such packer construction, and a second chamber subsequently to receive fluid pressure acting to urge the actuator in a direction relieving packer constriction to allow expansion of the packer away from the string, the pressure in the first chamber being subjected to increase to excessive level in response to engagement of an enlargement (such as a joint) in the string with the constricted packer and tending to expand same. The method steps include continuing the supply of actuating fluid pressure to the first chamber; and suddenly increasing the fluid pressure in the second chamber in response to the enlargement engagement with the packer. Typically, the sudden increase is effected by controllably by-passing to the second chamber excess pressurized fluid from the first chamber, and the by-passing is typically effected in response to detection of an increase of pressure in the first chamber. As a result, the enlargement or tool joint is found to pass through the constricted packer without substantially increased resistance to such passage, and without requiring reduction of speed of travel of the string, and also without materially increasing the rate of wear of the packer material.

In its apparatus aspects the invention comprises, in such a system as described, supply means to selectively supply actuating fluid pressure to the chambers; and modulator means in communication with the fluid pressure supply to the first chamber and operably to relieve such excess pressure development. Typically, the modulator means is in operative communication with the second chamber to effect sudden fluid pressure increase in the latter in response to sudden excess pressure development in the first chamber. As will be seen, the modulator means may include a by-pass valve controlling fluid pressure communication to the second chamber, together with biasing means (as for example the pressure of control fluid stored in an accumulator) yieldably biasing the by-pass valve toward a position blocking communication of actuating fluid pressure from the first to the second chambers.

Additional objects include the provision of a control valve (as for example a four-way valve) for controlling supply fluid pressure alternately to the first and second chambers as described, that valve having a position in which it communicates the second chamber with an outlet via piping of such length that an actuating pressure wave passed by the by-pass valve is supplied to the second chamber prior to transmission to the outlet via the control valve; the location of the by-pass valve either outside or inside a housing for the packer; the provision of a signaling circuit comprising a switch operable in response to by-passing of fluid to the second chamber via the modulator means and a signaling device (as for example on a drilling barge) electrically connected in circuit with the switch. Accordingly, the operator may elevate or lower the pipe so that the switch is not operated in response to vertical stroking of the string due to wave action on the barge, whereby he is assured that pipe joints are not passing up and down through the constricted packer, reducing wear thereof. Finally, the invention is applicable to use with string engaging tools other than radially constrictable packers, i.e., for example pipe rams.

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 description and drawings, in which:

DRAWING DESCRIPTION

FIG. 1 is an elevation showing a sub-sea well head assembly;

FIG. 2 is a vertical elevation, taken in section, showing a preventer assembly in closed or actuated condition;

FIG. 3 is a view showing a control system for the preventer, or similar preventers;

FIG. 4 is an elevation taken in section through a control valve in the FIG. 3 system;

FIG. 5 is a view showing a manually operable system for the preventer;

FIG. 6 is a fragmentary elevation showing a modification of the invention;

FIGS. 7–9 are schematic showings of modified systems; and

FIGS. **10–12** are sections showing modified control valves.

DETAILED DESCRIPTION

Referring first to FIG. **1**, the blow-out preventer assembly **10** is shown connected in a sub-sea stack **100** also including a series of ram-type preventers **101**. A riser system **102** extends above the stack and is connected thereto by a well head connector **103**. Riser pipe extends to the sea surface, and typically to a drilling barge **104** or other installation, and it is clear that wave action will cause the barge to move up and down, displacing suspended pipe up and down in the riser and the blow-out preventers.

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**, and 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 body bore **12**. Sunk in the upper face of cap **16** are bolt holes **24** for the attachment of equipment thereabove. 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-member bores identified above.

The body **11** has an annular, upstanding flange **38** which engages the packer 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 **42**, **41** and **43**, respectively, and the respective cylinder defining walls which receive those portions.

Piston **41** divides body bore **14** into upper and lower 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 may be equal, for balancing purposes.

The actuator **39** has a downwardly and inwardly tapering 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 an elastomer 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 self-restoring 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 limitative 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 limitative. 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 inwardly contracted into sealing engagement with members positioned within its bore.

Included in the make-up 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 expantion and also, to a limited extent, movable individually with respect to the rubber as will later appear. Taken together, the rigid control elements may be considered as a radially expansible 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 vertical rib **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 sides 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 end to end of the plates. This will prevent the rubber which will flow during the constriction 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, annular portion **72** is considered as being that portion which extends radially from face **57** to the outer faces **67** of ribs **65**.

The packer is lowered, while cap **16** is detached, into the position of FIG. **2**, the actuator **39** then being in the fully down position, and the annulus **55** nicely fitting the upper portion of bore **53** without requiring appreciable radial constriction of the annulus. For positively limiting the downward movement of the annulus, a stop is provided in the form of 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**, while latter is annularly defined by the tube and the sleeve **80**, there being a seal at **78**.

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 the arrangement and operation may be reversed.

The sleeve **80** may be considered as part of the housing structure **11**, to which it is retained by the faster **81**. The sleeve **80** and body **11**, together with actuator piston portion **42** from 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 actuator. In particular, such downward force to b1 so counteracted may typically result from the static pressure p_2 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. **1** shows the riser **87** within which the mud flows to the surface. The mud pressure is applied to the packer P tending 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. See in this regard co-pending application Ser. No. 785,891, entitled, "Well Pressure Compensated Well Blowout Preventer" wherein the supply of counterbalancing fluid pressure to chamber **82** via pipe **84** is discussed.

Extending the description to FIG. **3**, 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, as illustrated, pressure fluid is delivered to pipe **52** for closing the preventer packer, and pressure fluid in pipe **51** is exhausted at **93** to the sea or returned to the surface. In the alternate position of the valve **92**, pressure fluid is delivered to pipe **51** for opening the preventer packer, and fluid in pipe **52** is exhausted to the sea or returned to the surface. As explained in the co-pending application referred to above, counterbalancing fluid pressure may also be supplied to chamber **82** via pipe **84**. Controls for the regulator **91** and valve **92** are indicated at **94** and **95**, and may be electrically operated from the surface.

Coming now to that portion of the description highlighting the invention, it will be noted hat the string **86** may typically have connectors or collars **110** interconnecting the string pipe lengths **111**, the connectors being of larger diameter than such pipe. It is often desired to maintain the packer closed about the pipe while the latter is run longitudinally into or out of the well or while the pipe moves up and down due to wave action on the barge, as referred to; and it is found that rapid vertical displacement of the connectors through the closed packer tends to excessively wear the packer rubber necessitating its replacement at great expense. In this regard, with several hundred pounds of closing fluid pressure applied to chamber **48**, excessive pressure builds up in the latter as the connector **110** engages the closed packer and attempts to expand it and thereby urge the actuator **39** downwardly.

In accordance with the invention, modulator means is provided in this environment, and in communication with the pressure supply to closing (i.e. first) chamber **48**, for relieving the excess pressure development in that chamber, that developed pressure at times being greater than 1,500 p.s.i. As will be seen, the relief is such as to enable the enlarged connector to pass without difficulty through the packer, i.e., without excessively wearing the packer while at the same time the packer remains in closed and annular sealing engagement with the connector and pipe string vertical speed not being reduced during such passage. Typically, a bypass passage or pipe may be provided as at **113** communicating between the chambers **47** and **48**, as for example via pipes **51** and **52**, and the modulator means may comprise a check valve unit as at **114** controlling the by-passing of excess fluid pressure from "closing" chamber **48** to "opening" chamber **47**.

FIG. **4** shows one form of modulating check valve unit which also accommodates biasing to control the pressure level at which such by-passing occurs. It comprises a body **115** having a threaded inlet **116** for bypass pipe branch **117** connected to pipe **52**, and a threaded outlet **118** to receive the terminal of by-pass pipe **113**. Received within the body bore **119** is a seat ring **120** against which a valving stopper such as a ball **121** is urged by a plunger stem **122**. The plunger or piston body **123** is urged by spring **124** toward the ball, the opposite end of the spring being seated by a plug **125** having threaded reception at **126** in the body **115**. In this regard, the effective area of the piston **123** may be equal to or greater than the effective area of the opening **120*a*** defined by the ball seat, so that the ball will be held closed against the seat prior to pressure increase in line **117** created by attempted passage of a connector through the closed packer.

Plunger **122** is also urged toward the ball **121** by control fluid pressure in chamber **127**, and supplied from an accumulator **128** via piping **129**. The accumulator receives fluid under pressure from the line **130** connecting the discharge side of the regulator **91** with the control valve **92**, there being a check valve **131** in line **130** downstream of the location **132** at which the accumulator communicates with line **130** via branch **133**. As a result, the control fluid pressure supplied by by-pass valve chamber **127** remains at a level in part determined by the regulator **91**, the excess pressure developing in the preventer closing chamber **48** being blocked by check valve **131** from communication to the accumulator. Check valve **131** is not needed if lines **129** and **250** or **250*a*** are sufficiently long, as for example where they extend from the surface.

When that excess pressure reaches a level determined by the regulated level and the tension of spring **124**, the by-pass valve stopper or ball **121** opens and the excess pressure is immediately communicated to the opening chamber **47**. Relief of pressure build-up in closing chamber **48** may typically occur within less than a second following its sudden build-up. Also, the extent of relief may be such that the connector freely passes through the packer, with clearance permitting slight fluid leakage therebetween, the advantages being minimum wear of the packer and rapid passage of the connector therethrough. In FIG. **3** control valve configuration, chamber **47** remains in communication via elongated pipe **134** with the discharge or outlet point **135**, so that the excess pressure may bleed at a slower rate to the discharge, due to the restriction to flow imposed by the pipe **134**. In other words, when valve stopper **121** opens, the excess pressure wave is first communicated to chamber **47**, and later to the discharge, causing a downward force on the piston **39** to open the packer P to allow free passage of tool joint **110** through the packer. Note that the pressure in the opening chamber **47** and in valve body bore **119** typically will not be less than that of the sea water at the sub-sea level of the equipment, during the time valve **92** is in the position shown in FIG. **3**. Accordingly, the pressure delivered by the regulator **91** to close the packer about the string **86** must be substantially greater than the sub-sea pressure at the equipment level. Regulator **91** may be conventional, and include a valve controlling diaphragm exposed to pressure in line **91*a*** and to spring tension adjusted by control **94**. Finally, accumulator **128** may be made integral with the modulator valve unit **114**. Check valve **131** may be eliminated if line **250** between the accumulator and the by-pass valve is of length such that the excess pressure wave is by-passed at **114** prior to return via line **250** to the accumulator.

FIG. **10** illustrates the provision of an adjustable insert **230** threaded at **231** into plug **125*a*** corresponding to plug **125** in FIG. **4**. Rotation of the insert adjusts the tension in spring **124*a***, for control of by-passing pressure.

A further feature of the invention concerns the provision of a signaling circuit comprising a switch or other means indicated at **140** in FIG. **3** operable in response to by-passing of the fluid by valve **114**, and a signaling device **141** (see FIG. **1**) electrically connected in circuit with the switch, as via cable **142**. The switch may be pressure responsive and in communication with fluid pressure in line **113**. Accordingly, the signaling circuit enables detection by the operator at the surface of an increase in pressure in the closing chamber **48** to excessive level, as results from passage of a connector **110** into or through the closed packer annulus, wave action of the drilling barge for example lifting or lowering the pipe to effect this condition. He may then adjust the pipe string as by lifting or lowering same so as to obviate the condition, at which point the signaling device **141** at the surface is no longer actuated on and off at wave cresting or troughing intervals, whereby wear of the packer is substantially reduced.

FIG. **5** illustrates a modified system characterized by hand operation, or hand-controlled operation of one or more of the valves **150**, and **151**. In one position of four-way valve **151**, actuating fluid pressure is applied to the packer closing chamber, (corresponding to chamber **48**) in the preventer assembly **153**; and likewise, in the alternate position of valve **151**, actuating fluid pressure is applied to the packer opening chamber (corresponding to chamber **47**). The above assumes that by-pass valve **150** remains closed. Upon the occurrence of excess pressure in the closing chamber, as communicated by the gauge **155**, the operator may momentarily open the by-pass valve **150** to bleed the excess pressure developed in the closing chamber (as by passage of a connector **156** through the closed packer) to the opening chamber, for the purpose and with the results described above.

The by-passing function may alternatively be effected within the preventer housing as by a valve **160** protectively housed in the wall of the housing **11*a*** of the blow-out preventer assembly, in FIG. **6**. Control pressure is led to the valve biasing piston **123*a*** as via a pipe **161**, the piston being retained in an insert **162**. By-pass ducts in the wall are seen at **163** and **164** communicating with chambers **48*a*** and **47*a*** at opposite sides of the actuator piston **41*a***. Ducts **49*a*** and **50*a*** correspond to ducts **49** and **50** in FIG. **2**.

Further, as seen in FIG. **3**, the by-passing function may be supplemented by use of a modulating valve **170** similar to valve **114**, and connected between pipe **84** and pipe **51**, to by-pass excessive pressure in chamber **82** to the opening chamber.

Referring to FIG. **7**, isolation is there provided between the opening and closing pressure lines **51*a*** and **52*a*** connected to the housing **11** and in FIG. **2**, and the modulated means generally indicated at **199**, the latter functioning to relieve excess pressure development in the closing chamber of the preventer unit **10**. Means **199**, which may be supplied as a separate and complete unit to be operatively combined with the preventer, includes the modulator or by-pass valve **200** having the same mode of operation as that shown in FIG. **4**. Pressure from the closing chamber of the preventer is supplied via line **201** to the inlet side of the valve; pressure from the outlet side of the valve is communicated to the preventer opening chamber via line **202**; and control pressure from line **201** is normally supplied to the piston side of the valve **200** via line **203**, shuttle valve unit **204**, and line **205**. An accumulator **206** is also connected with line **205**, and line **205** contains an orifice restriction at **198**.

If pressure in line **201** increases due to attempted passage of the pipe connector **207** through the packer within the preventer **10**, the by-pass valve opens and the excess pressure is supplied via line **202** to the opening chamber, as previously described. Any excess then flows via that chamber to line **51*a*** leading to the four-way valve and then to the surface or to the sea. If pressure is applied to the packer opening chamber via line **51***a*, that pressure is also communicated via line **202** to the by-pass valve and held in by ball **121**, as seen in FIG. 4; also that pressure will also be applied as control pressure to the accumulator and to the piston side of the modulator, but will not be communicated to the closing chamber because shuttle ball **204***a* will be displaced from seat **209** to seat **208**, in chamber **308**. Restriction **198** prevents sudden loss of accumulator pressure to exhausting line **201** or **202**, while ball **204***a* shifts position to block such loss. Note the accumulator pressure equals that in line **201** or **202** to which it is connected.

Referring to FIG. **8**, the construction is the same as in FIG. 7, excepting that the shuttle valve is eliminated, and instead control pressure is supplied to the accumulator **206** and to the piston side of the by-pass valve **200** from a surface control unit **210**, via piping **211**. This adds versatility, and permits the surface operator to determine when the modulator means is to be operative and inoperative. For example, he may supply sufficient control pressure to prevent the by-pass valve from operating should that be desired.

FIG. **9** is similar to FIG. **8**, and illustrates a modified system characterized by remote control of the biasing pressure applied to the piston chamber in the valve **200**, and from a pressure source different from that used to operate the preventer. The by-pass pressure level is determined by the adjustment at **213** of pressure regulator **212**, and that level could be substantially greater than the pressure supplied to the preventer via line **217** at times when the by-pass valve is to remain inoperative. Line **214** connects an accumulator **215** with the regulator, and the line **216** connects the regulator with the control piston side of the by-pass valve. Pressure from an accumulator **218** is supplied to line **217** via regulator **219** and four-way valve **220**. When valve **220** is in the alternate position, pressure is supplied via line **221** to the preventer opening chamber. The provision of two separated pressure sources **215** and **218** makes unnecessary the check valve seen at **131** in FIG. 3, isolation being provided at the pressure source.

Referring back to FIG. **8**, a pressure differential switch **320** (or flow switch) is located in a branch line **321** connected into line **202** at opposite sides of the orifice **222**. Electrical wiring **323** connects the switch with a surface indicator as at **141** in FIG. **1**, which signals when pressure from the closing chamber is by-passed to the opening chamber. The orifice **222** provides an increased differential pressure thereacross in response to the by-passing of increased pressure to the opening chamber, and sufficient to operate the switch. In FIG. **9**, a signaling pressure switch **230** is connected in the discharge line **231** from the four-way valve **220**, and upstream of the restriction means **232** in that line, the switch being operated when the excess pressure from line **201** is by-passed at **200** to line **202**, then to line **221**, the four-way valve and line **231**.

FIG. **11** illustrates the carriage by the actuator **39***a* of the by-pass valve unit **235**. The latter may for example include the valve stopper such as ball **236** biased against seat ring **237** by the yieldable biasing means in the form of a compression spring **238**. The latter is retained within a plug **239** threaded into the actuator piston **240** and **241**, and it acts on the ball **236** via a plunger **242** slidable within a bore **243** in the plug. Fluid by-passed by the ball escapes from closing chamber **244** to the opening chamber **245**, via ducts **246** and **247** in the actuator piston. A telescoping hydraulic control connection to the by-pass valve may take the form of a hollow pin **248** sealed at **248***a* and carried by the actuator piston **251** to slide up and down in the pin bore **249** formed in the body **250**, corresponding to housing **11** in FIG. **2**. This arrangement provides a hydraulic connection from port **258** through ports **300** and **301** and through which control fluid pressure enters the control fluid chamber **249***a* to urge the piston **242** toward the ball **236**. Actuator **251** also corresponds to actuator **39** in FIG. **2**. Opening pressure is led via porting **253** to the opening chamber **245**.

FIG. **12** illustrates a modified modulator valve unit **260** incorporated in a body **261** which also carries a check valve **262** (corresponding to check valve **131** in FIG. 3) and an accumulator **263** (corresponding to accumulator **128** in FIG. 3). The check valve unit **262** includes a ball check **264** spring urged at **265** against a seat ring **266**, and corresponds to check valve **131** of FIG. 3. When valve **264** opens, pressure is applied to the four-way valve (not shown) which may have a position applying pressure to port **272** to be described.

Pressure is communicated to the accumulator **263** via the porting **267** and **268**, such pressure also being communicated to the control piston **269** acting via plunger **270** to bias the modulator valve ball **271** against seat ring **271***a*. When the ball **271** is displaced upwardly off the seat, excess fluid pressure in port **272** (communicating with the closing chamber) escapes to side port **273** and to the opening chamber at the actuator piston in the manner as described in FIG. 3. A spring **274** assists in holding the ball **271** closed. Note insert legs **275** connected to the ring **271***a*, and retained by insert sleeve **276** defining the bore **277** in which the piston **269** works. Thus, ring **271***a* is held by legs **275** in sealing position.

Provision is also made for operation of a switch in a circuit controlling a suitable indicator, as at the surface in an off-shore embodiment. The switch arm in this case consists of a rod **278** carried by the piston **269** and projecting vertically for engagement with a terminal contact **279** upon upward displacement of the piston by the ball **271**, to complete the indicator circuit. Contact **279** is urged downwardly by a spring **280** adapted to yield upwardly as the ball **271** lifts the piston and rod **278**, insulation **281** and **282** confining the contact and spring against electrical contact with the insert **283** in which these elements are housed. The insert in turn fits within bore **284** within receptacle **285** carried by the body **261**. The spring has electrical circuit communication via terminal **286** with the indicator indicated schematically at **287**.

The accumulator unit **263** may comprise a piston **290** slidable in bore **291** to compress gas in chamber **292** in response to increased fluid pressure transmission to chamber **293**.

The apparatus of the invention may be used in either land or sub-sea installations. Also, the apparatus works equally well whether the pipe string is being run into or out of a well. Further, after relief of excess pressure in the closing chamber associated with passing of the pipe joint through the packer, the modulating valve closes and the original conditions of packer constriction about the pipe string are restored.

What is claimed is:

1. In a system that includes housing structure for passing a well string vertically therethrough, a string engaging tool movable generally laterally in the housing toward and away from the string, and a fluid pressure responsive actuator for the tool, there being first and second chambers in the housing to receive fluid pressure acting to urge the actuator in opposite directions, the fluid in the first chamber being subject to excess pressure development in response to engagement of a longitudinally passing string enlargement with the tool tending to displace the latter and the actuator, the combination comprising

a. supply means to selectively supply actuating fluid pressure to said chambers, and
b. modulator means in communication with the fluid pressure supply to the first chamber and operable to relieve said excess pressure development therein in response to entry of said enlargement into the tool.

2. The combination of claim 1 wherein said tool comprises a packer annulus which is radially constrictable by the actuator, and which is expansible radially in response to string joint passage forcibly therethrough.

3. In a system that includes housing structure for passing a well string vertically therethrough, a string engaging tool movable generally laterally in the housing toward and away from the string, and a fluid pressure responsive actuator for the tool, there being first and second chambers in the housing to receive fluid pressure acting to urge the actuator in opposite directions, the fluid in the first chamber being subject to excess pressure development in response to engagement of a longitudinally passing string enlargement with the tool tending to displace the latter and the actuator, the combination comprising

a. supply means to selectively supply actuating fluid pressure to said chambers, and
b. modulator means in communication with the fluid pressure supply to the first chamber and operable to relieve said excess pressure development therein,
c. the modulator means being in operative communication with the second chamber to effect a pressure increase therein in response to excess pressure development in the first chamber.

4. In a system that includes housing structure for passing a well string vertically therethrough, a string engaging tool movable generally laterally in the housing toward and away from the string, and a fluid pressure responsive actuator for the tool, there being first and second chambers in the housing to receive fluid pressure acting to urge the actuator in opposite directions, the fluid in the first chamber being subject to excess pressure development in response to engagement of a longitudinally passing string enlargement with the tool tending to displace the latter and the actuator, the combination comprising

a. supply means to selectively supply actuating fluid pressure to said chambers, and
b. modulator means in communication with the fluid pressure supply to the first chamber and operable to relieve said excess pressure development therein,
c. said modulator means including a pressure relief valve communicating with the fluid pressure supplied the first chamber.

5. In a system that includes housing structure for passing a well string vertically therethrough, a string engaging tool movable generally laterally in the housing toward and away from the string, and a fluid pressure responsive actuator for the tool, there being first and second chambers in the housing to receive fluid pressure acting to urge the actuator in opposite directions, the fluid in the first chamber being subject to excess pressure development in response to engagement of a longitudinally passing string enlargement with the tool tending to displace the latter and the actuator, the combination comprising

a. supply means to selectively supply actuating fluid pressure to said chambers,
b. modulator means in communication with the fluid pressure supply to the first chamber and operable to relieve said excess pressure development therein, and
c. a passage communicating between said chambers, said modulator means controlling fluid pressure communication from the first to the second chambers for effecting said relief of excess pressure development in the first chamber.

6. The combination of claim 5 including a signaling circuit comprising a switch operable in response to bypassing of fluid to the second chamber via the modulator means, and a signaling device electrically connected in circuit with the switch.

7. The combination of claim 6 including said well string suspended by a vessel to hang in the ocean and in a well below the ocean floor, said device being on the vessel and said switch being at a stack of well head equipment at the ocean floor.

8. The combination of claim 6 wherein the switch includes a spring-urged contact adapted to be displaced to increase the spring tension in response to said fluid by-passing.

9. The combination of claim 5 wherein said modulator means includes a by-pass valve controlling said fluid pressure communication from the first to the second chambers.

10. The combination of claim 9 wherein said by-pass valve is outside the housing.

11. The combination of claim 9 wherein said modulator means also includes biasing means yieldably biasing the valve toward a position blocking said fluid pressure communication from the first to the second chambers.

12. The combination of claim 11 wherein said biasing means includes control fluid pressure from a source out of communication with said chambers.

13. The combination of claim 11 wherein said biasing means comprises control fluid pressure, and a piston responsive to said control fluid pressure to transmit biasing force to the valve.

14. The combination of claim 13 in which said biasing means also includes a spring under tension, and means to adjust said tension.

15. The combination of claim 13 including piping communicating the modulator means and said first

chamber with the accumulator and of length such that an excess pressure wave from the first chamber is by-passed by said by-pass valve toward the second chamber prior to transmission of the wave via said piping to said accumulator.

16. The combination of claim **13** wherein said supply means includes a control valve having one position in which actuating fluid pressure is supplied to the first chamber but not to the second chamber, and a second position in which actuating fluid pressure is supplied to the second chamber but not to the first chamber.

17. The combination of claim **16** in which said control valve in said first position communicates the second chamber with an outlet and via piping of such length that an actuating fluid pressure wave passed by the by-pass valve is supplied to the second chamber prior to transmission to the outlet via the control valve.

18. The combination of claim **16** wherein said supply means includes a source of actuating fluid pressure and a pressure regulator connected between said source and the control valve.

19. The combination of claim **16** including an accumulator supplying said control fluid pressure.

20. The combination of claim **19** including a support body containing said accumulator and said by-pass valve.

21. The combination of claim **20** including a check valve contained by said body and operable to transmit pressure from the accumulator to said control valve but blocking reverse transmission therebetween.

22. The combination of claim **9** wherein said by-pass valve in inside the housing.

23. The combination of claim **22** wherein said by-pass valve is carried by the actuator.

24. The combination of claim **23** wherein the modulator means also includes yieladable biasing means biasing the valve toward a position blocking fluid pressure communication from the first to the second chambers.

25. The combination of claim **23** including a telescopic connection between the actuator and housing structure and defining porting through which control fluid pressure is transmissible to a biasing piston acting to bias the by-pass valve toward a position blocking said fluid pressure communication from the first to the second chambers.

26. For use in a system that includes housing structure for passing a well string vertically therethrough, a string engaging tool movable generally laterally in the housing toward and away from the string, and a fluid pressure responsive actuator for the tool, there being first and second chambers in the housing to receive fluid pressure acting to urge the actuator in opposite directions, the pressure in the first chamber being subject to increase to excessive levels in response to engagement of a vertically passing string enlargement with the tool tending to displace the latter and the actuator, the combination comprising

a. supply means to selectively supply actuating fluid pressure to the chambers, and

b. modulator means operable, while actuating fluid pressure is being supplied to the first chamber, to increase the fluid pressure in the second chamber and in response to displacement of the tool relatively away from the string so as to cause the actuator to move toward the interior of the first chamber.

27. The combination of claim **26** wherein said modulator means is in fluid pressure by-passing communication with said chambers in response to said tool displacement.

28. In the operation of a system that comprises annular packer means which is radially forcibly constricted to engage a well string being passed longitudinally therethrough, and means including a packer actuator forming a first chamber receiving fluid pressure acting to urge the actuator in a direction to effect said packer constriction, and a second chamber subsequently to receive fluid pressure acting to urge the actuator in a direction relieving packer constriction to allow radial expansion of the packer away from the string, the pressure in the first chamber being subjected to increase to excessive level in response to engagement of an enlargement on the string with the constricted packer and tending to expand the packer, the steps that include

a. continuing the supply of actuating fluid pressure to the first chamber, and

b. suddenly increasing the fluid pressure in the second chamber in response to said engagement.

29. The method of claim **28** wherein said sudden increase of fluid pressure in the second chamber is effected by controllably by-passing to the second chamber excess pressurized fluid from the first chamber.

30. The method of claim **29** wherein said by-passing is effected in response to detection of an increase of pressure in the first chamber to said excessive level.

31. For use in a sub-sea system that includes housing structure for passing a well string longitudinally therethrough, a string engaging tool movable generally laterally in the housing toward and away from the string, and a fluid pressure responsive actuator for the tool, there being first and second chambers in the housing to receive fluid pressure acting to urge the actuator in opposite directions, the pressure in the first chamber being subject to increase to excessive levels in response to engagement of a longitudinally passing string enlargement with the tool tending to displace the latter and the actuator, the combination comprising modulator means operable, while actuating fluid pressure is being supplied to the first chamber, to increase the fluid pressure in the second chamber and in response to increase of fluid pressure in the first chamber caused by force transmission from the enlargement to the actuator via the tool, said modulator means including a by-pass valve, biasing means including an accumulator for biasing the valve toward a position blocking actuating fluid pressure communication from the first to the second chambers, a first pipe to communicate the inlet side of the by-pass valve with the first chamber, a second pipe to communicate the outlet side of the by-pass valve with the second chamber, and means to controllably communicate fluid pressure to said accumulator to supply said control fluid pressure.

32. The combination of claim **31** wherein said last named means comprises a valve operable to communicate fluid pressure from said first pipe to said accumulator when the pressure in said first chamber increases to said excessive level, and to communicate fluid pressure from said second pipe to said accumulator in response to fluid pressure communication to said second chamber tending to hold said by-pass valve closed.

33. The combination of claim 31 wherein said last named means comprises a surface control, and an elongated pipe communicating said control with said accumulator.

34. The combination of claim 31 including a pressure differential switch connected across an orifice in said second pipe, said switch being operable to electrically control an indicator at the surface.

35. The combination of claim 31 including a four-way valve connected with said first and second pipes to selectively control actuating pressure supply thereto, the four-way valve having an outlet to which another pipe is connected to pass fluid exhausted from one of the first and second chambers, and a pressure switch connected in said other pipe.

36. In the operation of offshore drilling equipment wherein a pipe string extends longitudinally through a closed blow-out preventer at a sub-sea location, the preventer containing a fluid pressure chamber, the string including connectors of larger diameter than the pipe diameter, the steps that include

a. effecting longitudinal displacement of the pipe,
b. detecting pressure change in said chamber resulting from the movement of a connector into engagement with the sub-sea closed preventer, and
c. adjusting the pipe string longitudinally to move the connector away from the preventer.

37. The method of claim 36 wherein the equipment includes a drilling barge from which the string is suspended to be subject to up and down displacement due to wave action, said adjustment step being carried out to an extent preventing subsequent engagement of the connector with the closed preventer due to said up and down displacement.

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