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W. W. DOLLISON

3,216,731

WELL TOOLS

Filed Feb. 12, 1962

2 Sheets-Sheet 1

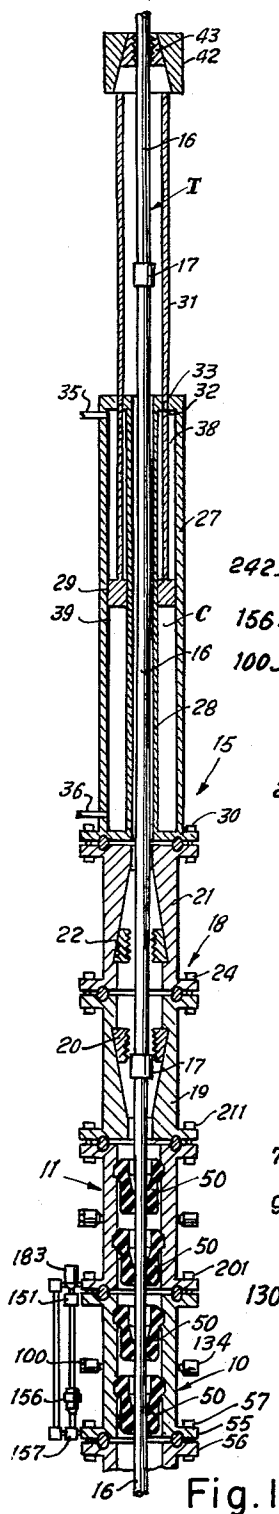


Fig. 1

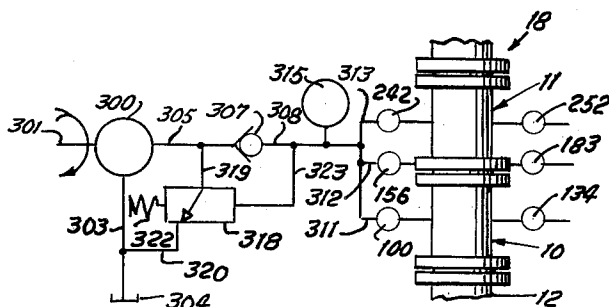


Fig. 8

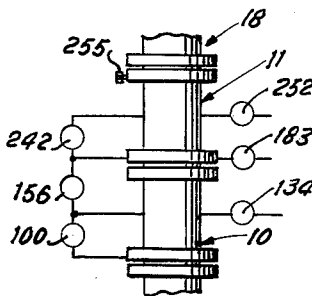


Fig. 6

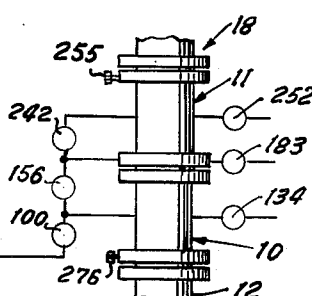


Fig. 7

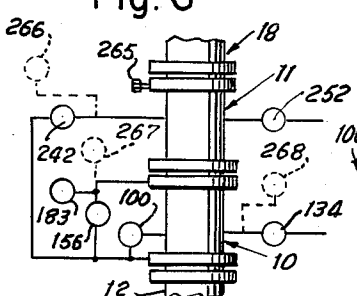


Fig. 5

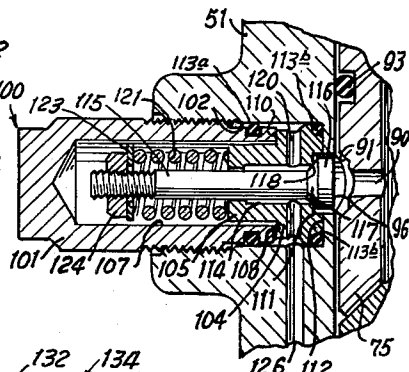


Fig. 3

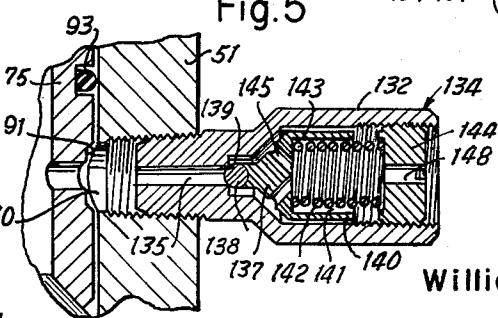


Fig. 4

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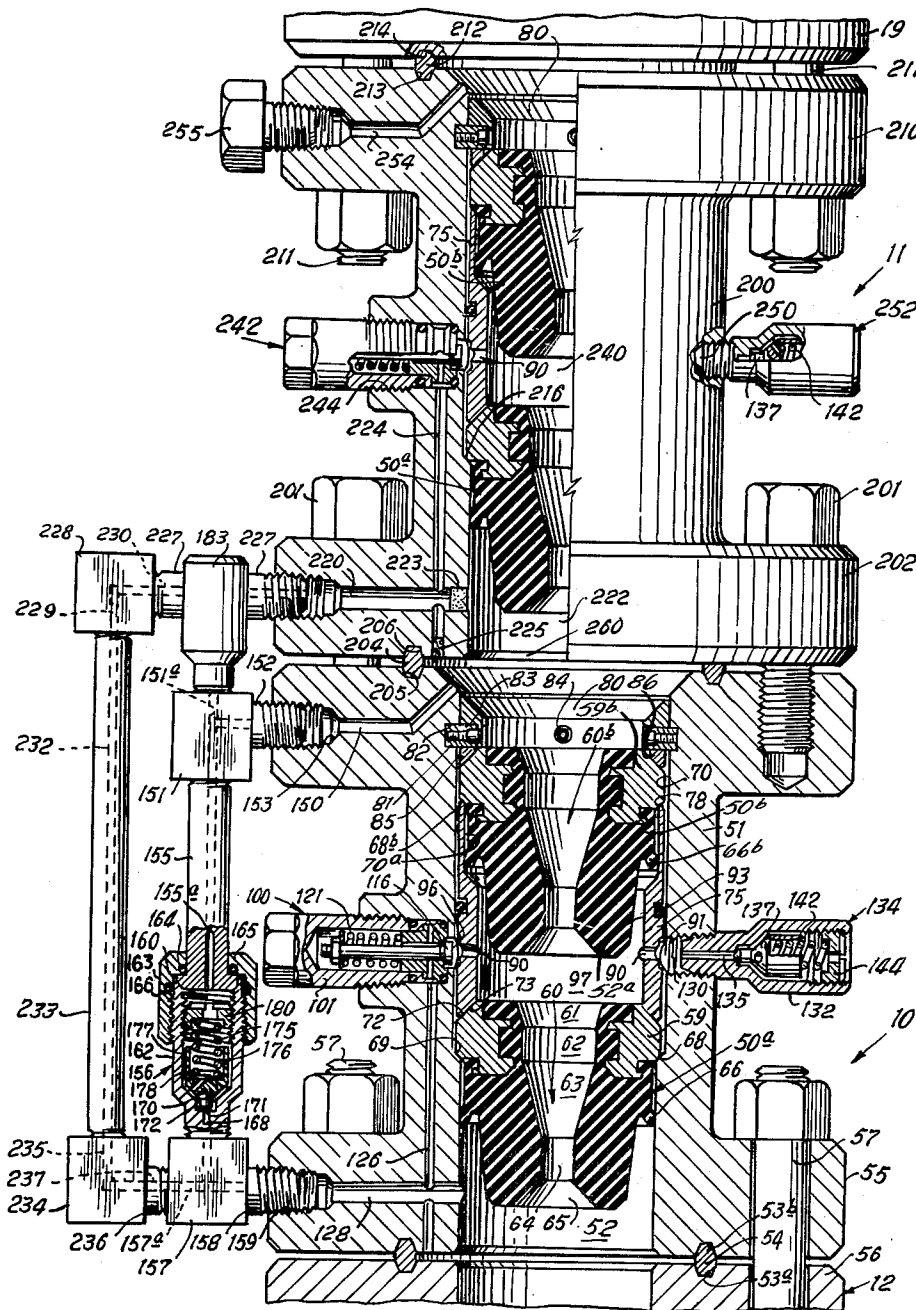


Fig. 2

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3,216,731

WELL TOOLS

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14 Claims. (Cl. 277-1)

This invention relates to well tools and to methods relating to wells and more particularly to blow out preventers for preventing escape of well fluids from a well during movement of a well flow conductor into or out of the well and methods for preventing such blow outs of well fluids.

An object of this invention is to provide a new and improved blow out preventer for preventing blow out or escape of well fluids from a well during the movement of a well flow conductor into or out of the well which does not slow down the operation of pulling out or running in of a well flow conductor of a well.

Another object is to provide a blow out preventer having a plurality of resilient elements engageable with a well flow conductor being run into or pulled out of a well to prevent escape of well fluids from the well during such running or pulling operations wherein the pressure to which each of the sealing elements is subjected is relatively low and only a fraction of the pressure of the well fluids whereby excessive wear of the resilient elements is avoided.

Another object is to provide a blow out preventer having a plurality of spaced resilient elements which engage the well flow conductor to prevent escape of well fluids from the well as the well flow conductor is run into or pulled out of the well wherein the resilient sealing elements are subjected to approximately equal pressure differentials thereacross with the pressure across each of the resilient elements being a fraction of the pressure of the well fluids.

A further object is to provide a blow out preventer having a plurality of resilient elements for engaging a well flow conductor being run into or pulled out of a well having automatic means for maintaining the pressure differential across each of the sealing elements at predetermined substantially constant values.

A still further object is to provide a blow out preventer having a plurality of low pressure sealing elements or strippers for engaging a well flow conductor being run into or pulled out of the well, each of which is subjected to a predetermined low pressure differential and which cumulatively retain the high pressure well fluids within the well and prevent their escape out of the well during such running and pulling operations.

Another object is to provide a blow out preventer having a plurality of vertically spaced resilient elements engageable with the well flow conductor and having means for maintaining substantially constant equal pressure differentials across each of the sealing elements to hold the sealing elements in sealing engagement with the well flow conductor being run into or pulled out of the well, the pressure below each of the resilient elements being higher than the pressure below the next resilient element positioned immediately thereabove.

Still another object of the invention is to provide a new and improved method for preventing blow out or escape of well fluids from a well during running in or pulling out of a well flow conductor into or out of a well by maintaining substantially constant pressure differentials across a plurality of longitudinally spaced sealing elements closing the annular space of the well about the well flow conductor to hold the sealing elements in sealing engagement with the well flow conductor with the pressure

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below each of the sealing elements being maintained at a value substantially higher than the pressure below the sealing element spaced immediately thereabove.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, wherein:

FIGURE 1 is a vertical sectional schematic illustration of a blow out preventer of the invention usable to practice the method of the invention mounted on a well head of a hydraulic snubbing apparatus employed therewith for running in or pulling out a well flow conductor, such as a tubing string, into or out of the well;

FIGURE 2 is an enlarged vertical partly sectional view of the blow out preventer;

FIGURE 3 is an enlarged sectional view of a pressure regulator of the blow out preventer of FIGURE 2;

FIGURE 4 is an enlarged sectional view of a pressure relief valve of the blow out preventer;

FIGURE 5 is a schematic illustration of the fluid pressure system of the blow out preventer illustrated in FIGURES 1 and 2 which employs the pressure of the well fluids to cause the sealing elements thereof to engage the well flow conductor;

FIGURE 6 is a schematic illustration of another fluid pressure system for the blow out preventer which employs the pressure of the well fluids for the operation thereof;

FIGURE 7 is a schematic diagrammatic illustration of a fluid pressure system for operating the blow out preventer wherein an external source of fluid under pressure is employed; and,

FIGURE 8 is a schematic illustration of still another fluid pressure system for the blow out preventer which also employs an external source of fluid under pressure.

Referring now particularly to FIGURES 1 through 5 of the drawing, the blow out preventers 10 and 11 embodying the invention are shown supported on the well head 12. A snubber apparatus 15 is mounted on the upper preventer 11 for running in or pulling out a well flow conductor, such as a tubing string T, formed of sections 16 connected by the usual collars or couplings 17.

The snubber apparatus may be of any suitable type such as a snubber apparatus illustrated and described in the United States patent application, Serial No. 103,351, filed April 17, 1961 by Phillip S. Sizer. The snubber apparatus may include a stationary snubber 18 having a lower section 19 having slips 20 which are employed to hold the tubing string against downward movement into the well and an upper section 21 having slips 22 which are employed to hold the tubing string against upward movement out of the well. The upper and lower sections of the stationary snubber are secured together in any suitable manner, as by the bolts 24. The slips of the stationary snubber may be moved into tubing string engaging positions by any suitable means which are not described in detail since they constitute no part of this invention.

The snubber apparatus 15 also includes a cylinder 27 having an internal cylindrical wall 28 to form an annular chamber C in which the annular piston 29 is movable. The cylinder is secured to the upper section 21 of the stationary snubber 18 by any suitable means as by means of the bolts 30. A cylindrical piston rod 31 extends upwardly from the piston 29 and through a suitable annular opening 32 in the top annular closure 33. Suitable seal means (not shown) of course are provided to seal between the piston rod and the top closure 33. Conduits 35 and 36 communicate with the upper and lower portions 38 and 39 of the chamber so that by selectively admitting fluid under pressure into one por-

tion and releasing fluid for the other portion through these conduits, the piston and the piston rod may be caused to move upwardly or downwardly as desired.

A traveling snubber 42 is secured to the upper end of the piston rod 31 and has slips 43 which are engageable with the tubing string. The means for operating the slips may be of any suitable type and have not been shown since the snubber apparatus constitutes no portion of this invention.

In FIGURE 1, the traveling snubber 42 is shown in use for forcing the tubing string T downwardly into the well against the pressure of the well fluids. It will be noted that the tubing string extends downwardly through the snubber 42, the cylindrical wall 28 of the snubber apparatus, the stationary snubber 18 and the blow out preventers 11 and 10 into the well head 12 and thence into the bore of the well. During the operations wherein the snubber 42 is in the position illustrated in FIGURE 1 and is being employed to force the tubing string downwardly into the well against the pressure exerted by the well fluids, the slips 43 of the traveling snubber 42 are caused to engage the tubing section while the piston is in its uppermost position and the slips 22 of the upper tubing section 21 are then moved to their retracted positions out of engagement with the tubing string. Fluid under pressure is then introduced into the upper portion 38 of the chamber C of the cylinder 27 through the conduit 35, while the fluid in the lower portion 39 of the chamber C is allowed to escape through the conduit 36, to cause the piston 29 to move downwardly and thus force the tubing string downwardly into the well. When the piston reaches the lower limit of its downward travel, the slips 22 of the upper stationary snubber 21 are caused to engage the tubing string to hold the tubing string against upward movement whereupon the slips 43 are moved out of engagement with the tubing string. The piston and the traveling snubber 42 are then moved upwardly to their initial upper positions by introducing fluid under pressure into the lower chamber 39 of the chamber C through the conduit 36 while permitting the fluid in the upper portion 38 of the chamber C to escape through the conduit 35. This cycle of operation can then be repeated so that the tubing string is moved incrementally downwardly into the well.

If the upper snubber is used to support the tubing string and control its downward movement and if the weight of the tubing string is sufficiently great to cause it to move downwardly by gravity, the position of the traveling snubber is reversed so that the slips 43 will tend to grip and hold the tubing string against downward movement relative to the snubber. The fluid in the lower portion 39 of the chamber is then released at a controlled rate, while fluid is permitted to enter into the upper portion of the chamber 38 through the conduit 35, so that the tubing string is permitted to move at a controlled rate downwardly into the well. When the piston and the traveling snubber reach the lower limits of their movement, the slips 20 of the lower section 19 of the stationary snubber 18 are caused to engage the tubing string to hold it against further downward movement. The slips 43 are then moved out of engagement with the tubing string and fluid under pressure is introduced into the lower portion 39 of the chamber C through the conduit 36, while the fluid in the upper portion 38 is permitted to escape through the conduit 35, to move the traveling snubber 42 back to its uppermost position whereupon the slips 43 thereof are again caused to engage the tubing string and the slips 20 are moved out of engagement with the tubing string so that this cycle of operation may again be repeated to permit another length of the tubing string to be moved downwardly at a controlled rate into the well.

It will be apparent that the snubber apparatus 15 may also be used to pull out the tubing string T or control its upward movement out of the well in the event that

the pressure of the fluids in the well is sufficient to expel the tubing string therefrom, in a similar way by the appropriate use of the stationary and traveling snubbers and by the controlled flow of fluids into and out of the upper and lower portions of the chamber C.

During movement of the tubing string T into or out of the well, the lower and upper sealing elements or strippers 50a and 50b of the blow out preventers 10 and 11 prevent blow out or escape of the well fluids from the well. The lower blow out preventer 10 includes a tubular body or head 51 having a longitudinal bore 52 in which are disposed the resilient sealing elements 50a and 50b. The adjacent surfaces of the well head and the head 51 are provided with aligned annular grooves 53a and 53b, respectively, in which are received lower and upper portions, respectively, of a seal ring 54 which seals therebetween. The head 51 is provided with a lower external flange 55 which is secured to the flange 56 of the well head 12 by means of bolts 57.

The lower sealing element 50a has an external retainer ring 59 at its upper end portion, the resilient sealing element being moulded to the retainer ring. The sealing elements are tubular in form having a central longitudinal bore or passage 60 defined by the upper outwardly beveled or flared surface 61, a substantially cylindrical upper internal surface 62, a downwardly and inwardly tapered surface 63, a cylindrical lower surface 64 and a lower downwardly and outwardly beveled or flared surface 65. The lower cylindrical surface 64 is of somewhat smaller diameter than the external surface of the tubing section 16 so that resilient sealing element is in an expanded or stretched condition when a tubing section 16 extends therethrough. The beveled upwardly facing surfaces 61 and 63 act as cam surfaces to help guide the tubing string downwardly through the sealing element and the coupling 17 thereof to prevent damage to the resilient sealing element, and to cause progressive stretching or expansion of the resilient sealing elements as the tubing sections and the couplings move downwardly and approach the lower cylindrical surface 64 which defines the narrowest section of the flow passage of the sealing element. The downwardly and outwardly beveled or flared surface 65 at the lower end of the sealing elements similarly helps to guide the tubing sections and the couplings upwardly to the cylindrical surface 64 of the sealing element and cause progressive stretching or expansion of the sealing element as the tubing string is moved upwardly through the sealing element point. An annular downwardly extending external lip 66 intermediate the ends of the sealing element is adapted to engage the internal surfaces of the head and seal thereagainst since upwardly acting fluid pressure in the passage 52 will tend to expand the lip against the head.

The retainer ring has a downwardly facing shoulder 68 adapted to engage the upwardly facing internal shoulder 69 provided in the passage 52 by the enlarged upper portion 70 thereof. The retainer ring 59 also has an upper downwardly and outwardly beveled shoulder 72 which is engaged by the lower annular similarly beveled shoulder 73 of a tubular adapter 75 disposed in the enlarged upper portion 70 of the bore 52.

The sealing element 50b is identical in structure to the sealing element 50a and components thereof have been provided with the same reference numerals to which the subscript b has been added as the corresponding components of the sealing element 50.

The retainer ring 59b of the upper sealing element 50b has its downwardly facing shoulder 68b engaging the upwardly facing shoulder 78 of the adapter 75 which limits downward movement of the upper sealing element in the head 51. The external annular lip 66b of the sealing element 50b engages the inner wall of the enlarged upper portion 70a of the bore 52a of the adapter. The lower and upper sealing elements 50a and 50b and the adapter are held against upward movement in the bore or passage 52 of the head 51 above

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the shoulder 69 by a keeper ring 80 releasably secured to the head by a split ring 81 whose inner and outer portions extend into aligned external and internal recesses 82 and 83 of the head and of the retainer ring, respectively. The split ring is held against movement by the screws 84 which extend through suitable apertures of the keeper ring into threaded bores of the split ring. A bevel ring 85 has a downwardly and outwardly beveled shoulder 86 which engages the upper shoulder 72b of the keeper ring 59b of the upper sealing element 50b and an upper surface which engages the lower surface of the split ring.

The adapter 75 is provided with a plurality of lateral apertures or ports 90 which communicate with an external annular recess or groove 91 thereof. The groove 91 is below a sealing means, such as an O-ring 93, disposed in a suitable annular recess of the adapter which seals between the adapter and the head.

The head 10 is provided with a lateral port 96 which communicates with the external annular recess 91 of the adapter head so that fluid under pressure may be admitted into the chamber 97 within the adapter between the lower and upper sealing elements.

Flow of fluid into the chamber 97 through the lateral port 96 of the head is controlled by a pressure regulator valve 100 which includes a housing 101 threaded into the enlarged portion 102 of the lateral port 96. A valve seat 104 has a reduced portion 105 which extends laterally outwardly into the bore 107 of the housing 101. The valve seat is held in position in the port 96 by the engagement of the inner annular shoulder 108 of the housing 101 with the annular shoulder 110 of the valve seat and the engagement of its annular end surface 111 with the shoulder 112 provided by the enlarged portion 102 of the port 96. The valve seat has an external annular recess in which a sealing means, such as an O-ring 113b is disposed to seal between the head and the valve seat. The housing is provided with a similar sealing means, such as an O-ring 113a disposed in an external annular recess thereof which seals between the head and the housing.

The valve seat 104 has a bore 114 through which extends the valve stem 115 of the valve head 116 whose beveled shoulder 117 engages with the annular edge or shoulder 118 of the valve seat to close the bore 114 of the valve seat inwardly of the transverse flow passage 120 of the valve seat. The opposite ends of the transverse flow passage open outwardly into the enlarged portion 102 of the port 96 and into an annular passage about the valve head formed between seal means 113a and 113b. The valve head 116 is biased toward engagement with the valve seat by a spring 121 disposed about the valve stem whose opposite ends bear against the inner end surface of the reduced portion 105 of the valve seat and the washer 123 disposed about the valve stem and held against outward movement thereon by a nut 124 threaded on the valve stem. It will be apparent that the force with which the spring 121 biases the valve head toward engagement with the valve seat shoulder 118 may be adjusted by rotation of the adjusting nut 124 in one direction or another on the valve stem.

The head 51 of the blow out preventer is also provided with a longitudinal passage 126 whose upper end communicates with the enlarged portion 102 of the port 96 between the O-rings 113a and 113b and whose lower end intersects a lower transverse passage 128 of the head and opens downwardly of the head inwardly of the seal ring 54. The lower transverse passage 128 of the head opens inwardly into the bore 52 below the lower sealing element 50a.

It will be apparent that the fluid in the bore 52 below the lower sealing element 50a may flow upwardly through the longitudinal passage 126 to the enlarged portion 102 of the port 96, thence through the passage 120 and bore 114 of the valve seat 104 and through the lateral

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port 96 of the head into the bore 52 between the upper and lower sealing elements, and then through the ports 90 of the adapter into the chamber 97 under the control of the pressure regulator valve 100. It will be apparent that the pressure regulator valve will maintain the pressure in the chamber 97, when a tubing string extends through the lower blow out preventer, at a predetermined value which is lower than the pressure in the bore 52 below the lower valve head. The pressure regulator valve opens whenever the pressure differential between the chamber 97 and the bore 52 below the lower sealing element 50b rises above value predetermined by the adjusted position of the adjusting nut 124, it being apparent that the fluid pressure acting through the longitudinal passage 126 tends to move the valve head towards its open position and the pressure within the chamber 97 tends to assist the valve spring 121 in biasing the valve head towards its closed position.

The head 21 is also provided with a lateral port 130 which opens into the bore or passage 52 of the head and communicates with the external recess 91 of the adapter head below the O-ring 93 thereof. The housing 132 of a pressure relief valve 134 is threaded into the lateral bore 130. The pressure relief valve 134 permits flow of fluids from the chamber 97 whenever the pressure within the chamber 97 exceeds a predetermined value. The pressure relief valve housing has a passage 135 which is closable by a valve body 137 whose rounded seat face 138 is engageable with the annular seat 139 of the housing. The valve body 137 has an enlarged spring retainer portion 140 provided with a recess 141 in which is disposed a biasing spring 142 one of whose ends bears against the shoulder 143 of the valve and whose other end bears against the adjusting screw 144 threaded into the outer end of the housing. The valve body 137 may be provided with the passages 145 which communicate with the interior of the spring retainer recess to facilitate flow of fluid through the housing when the valve body 137 is moved to open position against the resistance of the spring 142. The adjusting screw has an orifice 148 through which the fluid may escape to the atmosphere from the relief valve housing.

It will be apparent that the pressure relief valve is responsive to the pressure within the chamber 97 whenever such pressure exceeds a predetermined value. Rotation of the adjusting screw 144 in one direction or the other will of course change this predetermined value as desired.

The head 51 is also provided with an upper lateral passage 150 whose inner end opens into and communicates with the bore 52 of the head above the keeper ring 80 and the upper sealing element 50b and whose outer end communicates with the lower transverse passage 128 through the connector 151 which has a T fitting 152 threaded in the enlarged outer end portion 153 of the upper transverse passage, the conduit 155 whose upper end is threaded into the T connector 151, the pressure regulator valve 156 connected to the lower end of the conduit 155, T connector 157 whose fitting 158 is received in the threaded enlarged portion 159 of the lower transverse passage 128, the pressure regulator valve 156 also being connected to the T connector 157.

The T connectors are provided with the usual T-shaped flow passages 151a and 157a, respectively. The upper end of the conduit 155 is threaded into one end of the connector 151 so that the upper end of its passage 155a communicates with the passage 151a of the connector. The lower end of the conduit 155 is provided with an external annular flange 160 which is secured to the upper end of the housing 162 by a cap 163 threaded on the upper end of the housing. A sealing means, such as an O-ring 164, is disposed between the internal flange 165 of the cap and the upper surface of the conduit flange 160 to seal therebetween and a sealing means, such as an O-ring 166, is disposed in an

internal annular recess of the cap 163 to seal between the cap and the pressure regulator valve housing below the flange.

The pressure regulator valve 156 is identical in all other respects to the pressure relief valve 134 illustrated in FIGURE 3, the housing 162 being threadedly connected to the lower T connector 157 so that its passage 168 is in communication with the T-shaped passage 157a of the T connector. The flow of fluid through the pressure regulator valve 156 is controlled by the valve body 170 having an arcuate surface 171 of its lower end engageable with an annular valve seat 172 to close the flow passage 168. The valve body is biased toward closed position by the biasing spring 175 whose lower portion is disposed in the recess 176 of the spring retainer portion 177 of the valve body with its lower end bearing against the upwardly facing shoulder 178 and its upper end bearing against the adjusting screw 180 threaded into the housing. It will be apparent therefore that the pressure regulator valve 156 will open to permit fluid to flow from the bore 52 of the head 10 below the lower sealing element 50a into the bore 52 above the keeper ring whenever the pressure differential between the upper and lower portions of the bore 52 above and below the sealing elements exceeds a value predetermined by the position of the adjusting screw 180.

A pressure relief valve 183, identical in all respects with the pressure relief valve 134 is connected to the connector head 151 to permit flow of fluid from its passage 151a. The pressure relief valve 183 opens to permit escape of fluid from the bore 52 of the head above the upper sealing element 50b whenever the pressure at this point exceeds a predetermined value.

The upper blow out preventer 11 is substantially identical in all respects to the lower blow out preventer 10 having a body 200 secured to the head 51 of the lower blow out preventer by means of the bolts 201 which extend through suitable apertures in the lower external flange 202 of the head 200 into suitable threaded bores in the upper external flange of the lower head. A seal ring 204 whose lower and upper portions are received in the aligned annular recesses or grooves 205 and 206 of the adjacent upper and lower surfaces of the two heads seal therebetween. The upper flange 210 of the head 200 of the upper blow out preventer is secured to the lower section 19 of the stationary snubber 18 by means of bolts 211. A suitable sealing ring or gasket 212 has upper and lower portions which are received in the aligned grooves 213 and 214 of the head and of the snubber 19, respectively, to seal therebetween.

The upper blow out preventer 11 has upper and lower sealing elements 50a and 50b which are held in spaced relationship by an adapter 75. The assembly of the two sealing elements and the adapter 75 is disposed between the annular shoulder 216 of the head and the retainer ring 80 secured to the head by screws 84 in the same manner as are secured the sealing elements of the lower blow out preventer.

The head 200 has a lower transverse passage 220 similar to the lower transverse passage 128 of the head 51 whose inner end does not communicate with the bore or passage 222 of the head 200 since its inner end is closed, in any suitable manner, as by a weld 223. The longitudinal passage 224 of the head 200 which corresponds to the longitudinal passage 126 of the head 51, which intersects and communicates with the lower transverse passage 220, is closed by a weld 225. One conduit 227, has one end threaded in the outer enlarged end portion of the transverse passage 220 and has its other end threaded in a suitable bore of an upper connector 228. The connector 228 has an L-shaped passage 229 which communicates with the bore 230 of the conduit 227 and the bore 232 of a conduit 233 whose upper end is threaded in a suitable bore of the upper connector 228 and whose lower end is threaded into a bore of a lower connector 234. The

connector 234 has an L-shaped passage 235 which is in communication with the bore 232 of the conduit 233 and also with the bore 237 of a fitting 236 connected thereto. The fitting 236 is threaded in a bore of the T connector 157 and its bore 235 is in communication with the passage 157a of the T connector and thus with the passage 128.

Flow of fluid from the bore 52 of the lower blow out preventer into the chamber 240 between the upper and lower sealing elements of the upper blow out preventer is controlled by a pressure regulator valve 242 identical in all respects with the pressure regulator 100. The pressure regulator valve 242 is identical in structure with the pressure regulator valve 100 and, accordingly, the various components of the pressure regulator valve 242 have been provided with the same reference characters as the corresponding elements of the pressure regulator valve 100.

The housing 101 of the pressure regulator valve 242 is threaded in the enlarged portion 244 of a lateral port of the head 200. The lateral port communicates with the chamber 240 and also with the upper end of the longitudinal passage 224 of the head. The spring 121 of course holds the valve head 116 in closed position preventing flow from the longitudinal passage 224 into the valve of the head until the pressure differential therebetween exceeds a predetermined value.

The head 200 of the upper blow out preventer is also provided with a lateral port 250 which communicates with the chamber 240 through the ports 90 of the adapter 75 and in whose threaded portion is secured a pressure relief valve 252 whose structure is identical to that of the pressure relief valve 134. The components of the valve 252 are therefore provided with the same reference characters as the corresponding components of the pressure relief valve 134. The pressure relief valve 252, of course, prevents the pressure within the chamber 240 of the head from exceeding a predetermined value. The head 200 has an upper transverse passage 254 which however is plugged or closed by the plug 255 in such installations as that illustrated in FIGURE 1 wherein only two blow out preventers are employed.

In use, when the blow out preventers of the invention are employed to prevent the escape of well fluids from the well during movement of the well flow conductor, such as tubing string T, into or out of the well, and if, for example, the pressure of the well fluids is ten thousand pounds per square inch, the pressure regulator valve 100 is adjusted by rotation of its nut 124 so that it will open whenever the pressure differential between the bore 52 of the lower blow out preventer below the lower sealing element 50a and the chamber 97 between the two sealing elements thereof exceeds two thousand five hundred pounds per square inch. As a result whenever the pressure within the chamber 97 drops below seven thousand five hundred pounds per square inch, the pressure regulator valve 100 will open to permit the flow of well fluids into the chamber 97 until the pressure in the chamber 97 is again raised to seven thousand five hundred pounds per square inch. The relief valve 134 is adjusted to open whenever the pressure in the chamber 97 rises a predetermined degree above seven thousand five hundred pounds per square inch, say to seven thousand five hundred fifty pounds per square inch, so that the pressure within the chamber 97 will not fall below seven thousand five hundred pounds per square inch and will not rise above seven thousand five hundred fifty pounds per square inch. As a result, the pressure differential across the lower sealing element never exceeds a predetermined value, in this case approximately two thousand five hundred pounds per square inch.

The pressure regulator valve 156 is adjusted to open whenever the pressure differential between the bore 52 of the lower head below the lower sealing element 50a and the chamber 260 formed by the two heads of the two blow

out preventers and between the sealing element 50b of the lower blow out preventer and the sealing element 50a of the upper blow out preventer exceeds five thousand pounds per square inch. The pressure relief valve 183 is adjusted to open at a value slightly higher than five thousand pounds per square inch, say five thousand fifty pounds per square inch, so that the pressure within the intermediate chamber 260 is held within the range of five thousand pounds per square inch to five thousand fifty pounds per square inch. It will thus be apparent that the upper sealing element 50b of the lower blow out preventer is subjected to a pressure differential of approximately two thousand five hundred pounds since the pressure in the chamber 97 of the lower blow out preventer is maintained at approximately seven thousand five hundred pounds per square inch.

The pressure regulator valve 242 is similarly adjusted to open whenever the pressure differential between the bore 52 of the lower blow out preventer below the lower sealing element 50a thereof and the chamber 240 of the upper blow out preventer exceeds seven thousand five hundred pounds per square inch so that the pressure regulator valve 242 will open whenever the pressure within the chamber 240 drops below two thousand five hundred pounds per square inch. The pressure relief valve 252 is adjusted to open at a value slightly higher than two thousand five hundred pounds per square inch, say two thousand five hundred fifty pounds per square inch, so that the pressure within the chamber 240 is held within the range of two thousand five hundred pounds per square inch and two thousand five hundred fifty pounds per square inch.

It will now be seen that each of the sealing elements of the lower and upper blow out preventers 10 and 11 is held in sealing engagement with the tubing string which extends therethrough by a pressure differential of approximately two thousand five hundred pounds per square inch so that the full pressure of ten thousand pounds per square inch of the well fluids is in effect staged across the sealing elements of the blow out preventers and no sealing element is subjected to pressure differentials greater than approximately two thousand five hundred pounds per square inch as the tubing string is moved either downwardly or upwardly through the blow out preventers by a suitable snubber apparatus, such as the snubber apparatus 15 illustrated in FIGURE 1.

The pressure within each of the chambers 240, 260 and 97 tends to rise sharply each time a coupling 17 moves thereto because the movement of a coupling into a chamber reduces the volume of the chamber. The pressure within each chamber however remains substantially constant since the pressure relief valves 252, 183 and 134 allow the escape of fluid from each chamber as the couplings pass thereto to prevent the pressure therein from exceeding the predetermined value. As the couplings move out of the chambers, the pressure within the chambers tends to drop since the volumes of the chambers now increase. However, as the pressure in each chamber drops below the predetermined value, the pressure differential between such chamber and the bore 52 of the head 51 increases since the pressure of the well fluids remains substantially constant and the appropriate pressure regulator valve 100, 156 or 242 opens to permit flow of the well fluids into such chamber until the pressure within such chamber again attains the desired predetermined value.

It will now be seen that a new and improved blow out preventer for preventing escape of well fluids from a well during the movement of a well flow conductor into or out of the well has been illustrated and described which includes a tubular member or head connectible to the well head and having its bore in longitudinal alignment with the bore of the well, the tubular member being provided with a plurality of resilient sealing elements which seal between the well flow conductor and such tubular mem-

ber or head, the blow out preventer having means for regulating the pressure differential across each of the sealing elements so that the fluid pressure below each sealing element is greater than the pressure immediately thereabove and so that each sealing element is subjected to a pressure differential which is much smaller than the pressure differential between the atmosphere and the well fluids and bears only a portion of the force exerted by the pressure of the well fluids tending to flow between the well flow conductor and the tubular member.

It will further be seen that the means for subjecting the sealing elements of the blow out preventer to a predetermined pressure differential includes pressure regulator valves for admitting fluid under pressure into the tubular member between adjacent spaced sealing elements of the blow out preventer to maintain the pressure differential across such sealing elements at predetermined values and with relief valves for preventing the pressure between adjacent ends of adjacent sealing elements from exceeding predetermined values.

It will be apparent that the well flow conductor, such as a tubing string having externally extending couplings or collars 17, may be moved continuously through the sealing elements of the blow out preventers without the necessity of stopping movement of the tubing string each time a coupling is moved through the blow out preventer as is necessary where conventional ram type blow out preventers are used.

It will further be seen that the blow out preventer includes a head having a pair of resilient sealing elements 50a and 50b which are held in longitudinally spaced positions by adapter 75 to provide a chamber between the sealing elements, that fluid under pressure is admitted into the chamber through a pressure regulator valve and that fluid is allowed to escape from the chamber through a pressure relief valve so that the pressure within such chamber is maintained at a substantially constant predetermined value.

It will further be seen that the pressure relief valves permit escape of fluid from the chamber as the volume of the chamber is decreased by the passage of a tubing string thereto to prevent the pressure therein from increasing above predetermined value and that the pressure regulator valves permit flow of fluids into such chamber as the volume of the chamber is increased upon the movement of a coupling or collar 17 out of the chamber to prevent the pressure therein from falling below a predetermined value.

It will now be seen that the method of the invention for preventing blow out or escape of well fluids from a well during movement therethrough of a well flow conductor which may or may not have spaced external annular flanges, such as couplings, includes disposing a plurality of longitudinally spaced sealing elements about the well flow conductor to engage the well flow conductor to close the annular space thereabout and to form chambers between adjacent ends of adjacent sealing elements and about the well flow conductor, introducing fluid pressure into the chambers to create a predetermined pressure differential across each of the sealing elements tending to hold the sealing element in sealing engagement with the well flow conductor, and maintaining the pressure within each chamber at a predetermined value which is lower than the pressure to which is subjected the lower end of the sealing element defining the lower end of the chamber.

The method also includes the step of permitting fluid to escape from each chamber as an external flange of the well flow conductor enters into such chamber and decreases the volume of the chamber to prevent the pressure within the chamber from exceeding a predetermined value and the step of permitting fluid under pressure to enter each chamber as an external flange leaves the chamber to prevent the pressure within the chamber from falling below a predetermined value.

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If desired, as indicated in broken lines in FIGURE 5, accumulators 266, 267 and 268 may be connected to the blow out preventers in such manner that they are placed in communication with the chambers 240, 260 and 97, respectively, in order to minimize the flow of fluids through the pressure regulator valves and the pressure relief valves. Each accumulator may be in the form of a closed container, a portion at least of which is filled with a compressible gas so that fluid from each of the chambers of the blow out preventers will tend to flow into its associated accumulator thus further compressing the gas in the accumulator as a coupling enters into such chamber and reduces its volume and will flow therefrom and into its associated chamber as the collar of the well flow conductor moves out of such chamber and thus increases its volume. In this manner the flow of fluid through the pressure regulator and pressure relief valves is minimized which may be desirable where the well fluids contain sand, mud or other abrasives which tend to damage the seating surfaces of such valves.

It will be apparent that when the pressure regulator valves 100, 156 and 242, as shown in FIGURES 1, 2 and 5, are connected in parallel with the bore 52 of the head 51 of the lower blow out preventer 10 below the lower sealing element 50a thereof, the pressure regulator valve 242 must regulate the flow of fluids when subjected to a higher pressure differential than the other two pressure regulator valves and that the pressure regulator valve 100 must regulate the flow of fluids when it is subjected to a predetermined but lower pressure differential than the other two pressure regulator valves. If desired, the pressure regulator valves may be connected in series, as illustrated schematically in FIGURE 6, to the source of fluid pressure in order that each of the pressure regulator valves may be subjected to the same pressure differential. It will be noted that the pressure regulator valve 100 is connected between the bore 52 of the lower head 51 below the lower sealing element 50a of the lower blow out preventer and the chamber 97 thereof between its upper and lower sealing elements so that the pressure on the upstream side of the pressure regulator 100 in the given case is ten thousand pounds per square inch and the pressure on the downstream side is approximately seven thousand five hundred pounds per square inch. The pressure regulator valve 100 is then subjected to a pressure differential of approximately two thousand five hundred pounds per square inch. The pressure regulator valve 156 has its inlet end in communication with the downstream or outlet end of the pressure regulator valve 100 while its downstream or outlet end is connected to the chamber 260 between the lower and upper sealing elements of the upper and lower blow out preventers 10 and 11 so that its upstream or inlet end is subjected to a pressure of seven thousand five hundred pounds per square inch and its downstream or outlet end is subjected to a pressure of five thousand pounds per square inch. The pressure regulator valve 156 is thus subjected to a pressure differential of two thousand five hundred pounds per square inch. The pressure regulator valve 242 has its upstream or inlet end connected to the downstream or outlet end of the pressure regulator valve 156 and its downstream or outlet end connected to the chamber 240 of the upper blow out preventer 11 so that its upstream end is subjected to a pressure of five thousand pounds per square inch and its downstream end is subjected to a pressure of two thousand five hundred pounds per square inch. This pressure regulator valve, like the other two pressure regulator valves, is thus subjected to a pressure differential of approximately two thousand five hundred pounds per square inch. It will thus be seen that the pressure regulator valves when connected in series as illustrated in FIGURE 6 are each subjected to equal pressure differentials. The relief valves 134, 183 and 252 are of course adjusted to open at some value slightly higher than seven thousand five hundred pounds per square inch,

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five thousand pounds per square inch, and two thousand five hundred pounds per square inch, respectively.

In the event that the well fluids contain excessive amounts of sand, mud or other abrasives or are highly corrosive, the chambers 97, 260 and 240 between the sealing elements of the blow out preventers 10 and 11 may be provided with clean fluids under pressure from an external source 275 which may be another well producing relatively clean fluids or which may be a hydraulic pump. In this event, the lower transverse passage 128 of the head 51 of the lower blow out preventer would be provided with an external plug 276, similar to the plug 255 illustrated in FIGURE 2, to close the outer end of the lower transverse passage 128 while the inner end of the transverse passage 128 is closed in the same manner as the lower transverse passage 220 of the upper blow out preventer 11 is closed by the weld 223. The lower end of the longitudinal passage 126 of the head 51 of the lower blow out preventer is also closed at its lower end in the same manner that the longitudinal passage 224 of the head 200 of the upper blow out preventer 11 is closed by the weld 225. As shown in FIGURE 7, the external source of fluid under pressure is connected to the chambers between adjacent sealing elements of the blow out preventers with the pressure regulator valves thereof connected in series.

It will be apparent of course that the pressure regulator valves could be connected in parallel between the chambers and the external source of fluid under pressure as is shown in FIGURE 8 wherein the hydraulic pump 300 is employed as the source of fluid under pressure. The drive shaft 301 of the pump 300 is driven by any suitable prime mover such as an electric motor (not shown). The inlet duct 303 of the pump extends and opens into a reservoir tank 304 of the liquid which is to be delivered to the chambers 97, 260 and 240 formed by the two blow out preventers through the regulator valves 100 and 156 and 242, respectively. The outlet conduit 305 of the pump 300, which has a check valve 307 connected therein to prevent reverse flow of fluid therethrough is connected to the conduit 308 whose parallel branches 311, 312 and 313 are connected to the inlet ends of the pressure regulator valves 100, 156 and 242. A pressure accumulator 315 may be connected in communication with the conduit 305 between the pressure regulator valves and the check valve 307. The pressure accumulator has at least a portion thereof filled with compressible gas. An overload dump valve 318 may be connected by means of the conduits 319 and 320 across the outlet and inlet conduits 305 and 303, respectively, of the pump 300. The overload dump valve is provided with a biasing spring 322 which biases the overload dump valve 318 towards closed position. The conduit 323 transmits the pressure of the fluid in the outlet line 305 to the overload dump valve to cause it to open whenever the pressure in the outlet line exceeds a predetermined value.

In operation, the fixed displacement pump 300, when initially placed in operation, pumps the liquid from the tank 304 and the regulator valves will permit flow of the liquid into the chambers of the blow out preventers until the pressure differential across each of the pressure regulator valves attains a predetermined value and the pressure accumulator is filled with liquid to a predetermined degree and held under a predetermined pressure by the thus compressed gas of the accumulator. When the pressure within the pressure accumulator 315 attains a predetermined value, the overload dump valve 318 opens since such pressure is transmitted thereto by the conduit 323. The pump 300 may therefore continue to operate even though no further fluid is permitted to flow past the check valve 307 and merely recirculates the fluid between its inlet and outlet conduits 303 and 305. Should the pressure within one of the chambers 97, 260 or 240 now drop to increase the pressure differential across one of the pressure regulator valves, such valve

opens and permits fluid to flow into such chamber causing the pressure within the conduit 305 to drop. This drop in pressure causes the pressure overload dump valve 318 to close and the pump will now cause fluid under pressure to flow through the check valve 307 to the pressure accumulator and to such chambers of the blow out preventer through the regulator valves.

While the outlet conduit 305 of the pump has been shown as connected to the conduit 308 whose parallel branches are connected to the regulator valves, it will be apparent that the outlet conduit 305 of the pump 300 could be connected to the upstream or inlet end of the pressure regulator valve 100 of the circuit as illustrated in FIGURE 7 wherein the pressure regulator valves are connected in series. It will now be seen that the pump 300 may be employed as the external source of fluid pressure for the blow out preventers.

The pressure of the well fluids may be of such value that only two sealing elements are necessary. For example, if each sealing element operates satisfactorily under a pressure differential thereacross of two thousand five hundred pounds per square inch and the pressure of the well fluids does not exceed five thousand pounds per square inch, only the lower blow out preventer 10 would be employed. In this case, the lower and upper transverse passages 128 and 150 of the head 51 would be closed to the outside by suitable plugs, such as the plug 255. The pressure regulator valve 100 would be adjusted to open when the pressure differential thereacross increased above two thousand five hundred pounds per square inch. The pressure regulator valve 134 would be set to open at a somewhat higher pressure, say two thousand five hundred twenty-five pounds per square inch. As a result, the pressure differential across the lower sealing element 50a would be maintained at approximately two thousand five hundred pounds per square inch since the pressure immediately therebelow would be five thousand pounds per square inch and the pressure immediately thereabove in the chamber 97 would be approximately two thousand five hundred pounds per square inch. Similarly, the upper sealing element 50a would be subjected to a pressure differential of approximately two thousand five hundred pounds per square inch since the pressure in the chamber 97 is maintained at approximately two thousand five hundred pounds per square inch and the upper end thereof is now exposed to the atmosphere since the upper blow out preventer 11 is not present.

It will be apparent that as many of the blow out preventers, connected serially one to another in longitudinal alignment, may be employed as desired depending upon the pressure of the well fluids and the pressure differential to which the individual sealing elements may be subjected without causing undue wear or deterioration of the sealing elements.

It will now be seen that a new and improved blow out preventer has been illustrated and described which employs any desired number of longitudinally aligned and spaced sealing elements in a tubular member which is placed in longitudinal alignment and in communication with the well, so that a well flow conductor may be moved through the sealing elements with the sealing elements sealing between the tubular member and the well flow conductor and that the tubular member may be composed of any number of the heads or sections.

It will further be seen that each of the sealing elements is subjected only to a fraction of the total pressure differential between the atmosphere and the well bore so that a plurality of sealing elements, each one of which is capable of satisfactorily resisting only a small pressure differential thereacross, may be employed to prevent blow out of the well fluids.

It will further be seen that the flow conductor may be moved continuously through the sealing elements without the necessity of arresting its movement each time an enlarged portion of the well flow conductor, such as the

coupling, moves past a sealing element so that the operation of running or pulling out of well flow conductor from the well requires a minimum expenditure of time and labor when the blow out preventers embodying the invention are employed.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A well tool including: a tubular member having a bore; a plurality of tubular sealing elements disposed in said tubular member in longitudinally spaced relation, said sealing elements being engageable with an elongate member movable through said tubular member and sealing therebetween to provide a plurality of longitudinally spaced chambers between each adjacent pair of sealing elements; and means providing for flow of fluid from the bore of the tubular member at a point upstream of one end sealing element exteriorly of the sealing elements and back into the tubular member into the chambers between said sealing means, said last mentioned means including pressure regulator means for maintaining the pressure in each successive chamber at a pressure reduced by a predetermined amount below the pressure in the chamber next upstream therefrom.

2. A well tool of the character set forth in claim 1 wherein, said pressure regulator means includes pressure regulator valve means controlling admission of fluid pressure to each of said chambers for preventing the pressure in each of said chambers between said sealing elements from decreasing below a predetermined value; and fluid pressure responsive release means for preventing the pressure in each of said chambers between said sealing elements from exceeding said predetermined value.

3. A well tool for preventing escape of well fluids from a well during movement of an elongate member into or out of the well including: a tubular member installable on the well and having a longitudinal passage in longitudinal alignment with the well bore; a plurality of tubular sealing elements disposed in said tubular member in longitudinally spaced alignment, said sealing elements being engageable with an elongate member movable through the tubular member for sealing therebetween, said tubular member, said elongate member and said sealing elements providing annular chambers between adjacent ends of adjacent: sealing elements; fluid pressure responsive regulating means for conducting fluid under pressure at predetermined reduced values from upstream of each of said sealing elements into the chamber between said sealing element and the next downstream sealing element; and fluid pressure responsive means communicating with the chamber between adjacent pairs of said sealing elements for releasing fluid pressure from said chamber when the pressure within the chamber exceeds a predetermined value, whereby a predetermined pressure reduction is maintained across each sealing element of the plurality of sealing elements decreasing in value from the most upstream sealing element to the most downstream sealing element.

4. A well tool for preventing escape of well fluids from a well during movement of an elongate member into or out of the well including: a tubular member installable on the well and having a longitudinal passage in longitudinal alignment with the well bore; a plurality of tubular sealing elements disposed in said tubular member in longitudinally spaced alignment, said sealing elements being engageable with an elongate member movable through the tubular member for sealing therebetween, said tubular member, said elongate member and said sealing elements providing annular chambers between adjacent ends of adjacent sealing elements; fluid pressure responsive regulating means for introducing fluid under pressure from upstream of each of said sealing elements into the cham-

ber between said sealing element and the sealing element next downstream thereof at a predetermined reduced lower pressure, whereby the pressure in the chambers between each of said sealing elements is introduced at a predetermined reduced value from the upstream to the downstream side of such sealing elements in each of said chambers; and pressure responsive means for releasing fluid from each of said chamber when the pressure within the chamber exceeds a predetermined value.

5. A well tool for preventing escape of well fluids from a well during movement of an elongate member into or out of the well including: a tubular member installable on the well and having a longitudinal passage in longitudinal alignment with the well bore; a plurality of tubular sealing elements disposed in said tubular member in longitudinally spaced alignment, said sealing elements being engageable with an elongate member movable through the tubular member for sealing therebetween, said tubular member, said elongate member and said sealing elements providing annular chambers between adjacent pairs of sealing elements; and means connectable to a source of fluid under pressure for introducing fluid under pressure into said chambers at a predetermined value in each of said chambers whenever the pressure within said chambers falls below said predetermined values, including means for maintaining the pressure in each of said chambers at a predetermined lower value than the pressure in the chamber next upstream, whereby the pressure across each of said sealing elements is reduced by a predetermined amount from upstream to downstream thereof.

6. A well tool for preventing escape of well fluids from a well during movement of an elongate member into or out of the well including: a tubular member installable on the well and having a longitudinal passage in longitudinal alignment with the well bore; a plurality of tubular sealing elements disposed in said tubular member in longitudinally spaced alignment, said sealing elements being engageable with an elongate member movable through the tubular member for sealing therebetween; said tubular member, said elongate member and said sealing elements providing annular chambers between adjacent ends of adjacent sealing elements; and means connectable to a source of fluid under pressure for introducing fluid under pressure into each of said chambers at a value reduced by a predetermined amount below the pressure in the chamber next upstream therebelow when the pressure within each of said chambers falls below said predetermined values, said predetermined pressure in each of said chambers being maintained at a lower value than the pressure in the next lower chamber; and fluid pressure responsive means for releasing fluid from each of said chambers when the pressure within the chamber exceeds a predetermined value.

7. The method of preventing escape of fluids from a well during movement of an elongate member into or out of the well including: disposing a tubular member having a longitudinal passage with a pair of longitudinally spaced tubular sealing elements therein in longitudinal alignment with the well, moving the elongate member through the longitudinal passage, and introducing fluid pressure from the well bore upstream of the lowermost chamber successively; into each annular chamber thereabove between adjacent sealing elements defined by said sealing elements, the tubular member and the elongate member to maintain a successively lower predetermined pressure differential across successive sealing elements tending to hold the sealing elements in sealing engagement with the elongate member and the tubular member; and maintaining the pressure within each chamber at a predetermined value which is lower than the value of the pressure in the chamber next below.

8. The method of preventing escape of fluids from a well during movement of an elongate member into or out

of the well including: disposing a tubular member having a longitudinal passage with a pair of longitudinally spaced tubular sealing elements therein in longitudinal alignment with the well, moving the elongate member through the longitudinal passage, and introducing fluid pressure into an annular chamber between adjacent sealing elements defined by said sealing elements, the tubular member and the elongate member to maintain a predetermined successively lower pressure differential across the sealing elements from the lowermost to the uppermost of said elements tending to hold the sealing elements in sealing engagement with the elongate member and the tubular member; permitting fluid to escape from the chamber whenever the volume of the chamber decreases and an enlarged portion of the elongate member moves into the chamber to prevent the pressure differential across of the lower sealing element from decreasing below a predetermined value, and permitting fluid to flow into the chamber as the volume of the chamber increases as an enlarged portion of the elongate members moves out of the chamber to prevent the pressure differential across the lower sealing element from increasing above a predetermined value.

9. The well tool of claim 5, wherein said means for maintaining fluid under pressure of predetermined value in each of said chambers includes pressure regulator valves, each of said pressure regulator valves regulating introduction of fluid into an associated chamber.

10. The well tool of claim 9, wherein said pressure regulator valves are connected in series to said source of fluid under pressure.

11. The well tool of claim 9, wherein said pressure regulator valves are connected in parallel to said source of fluid under pressure.

12. The well tool of claim 5, and pressure accumulator means connected to each of said chambers for minimizing flow of fluid into said chamber.

13. The well tool of claim 6, and pressure accumulator means connected to each of said chambers for minimizing flow of fluid into and out of said chambers.

14. A well tool for preventing the escape of well fluids from a well during movement of an elongate member into and out of the well including: a tubular member installable on the well and having a longitudinal passage in longitudinal alignment with the well bore; a plurality of tubular sealing elements disposed in said tubular member in longitudinally spaced alignment therein, said sealing elements being engageable with an elongate member movable through the tubular member for sealing therebetween, said tubular member, said elongate member and said sealing elements providing a plurality of longitudinally spaced annular chambers in said tubular member between adjacent ends of adjacent sealing elements, the volume of the chamber between adjacent sealing elements varying as portions of said elongate member of different external diameter are moved therethrough; and fluid pressure responsive means for controlling the pressure of fluid introduced into the chambers between said elements and maintaining said pressures in said chambers at predetermined fixed successively lower values from the lowermost chamber to the uppermost chamber.

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