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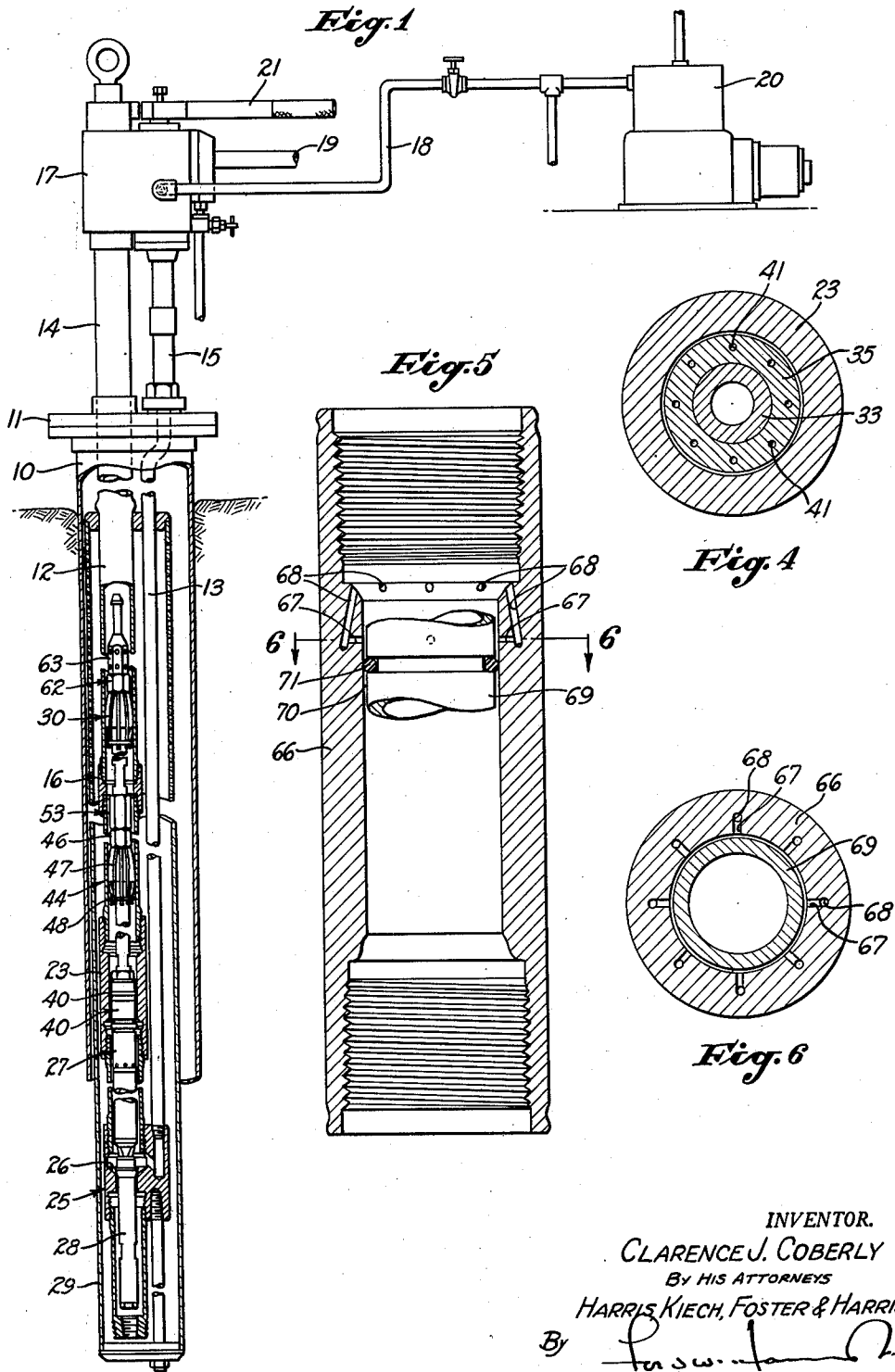
C. J. COBERLY

2,568,320

FLUID-OPERATED PUMP SYSTEM WITH PARALLEL TUBING

Filed Jan. 5, 1948

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2 Sheets-Sheet 2

Fig. 2

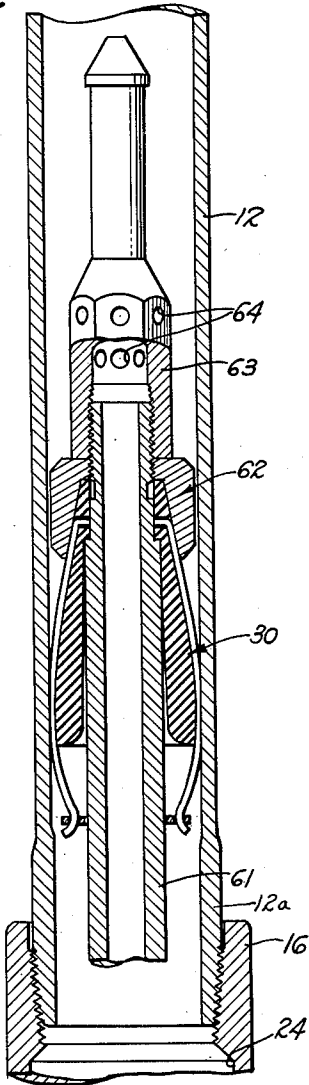
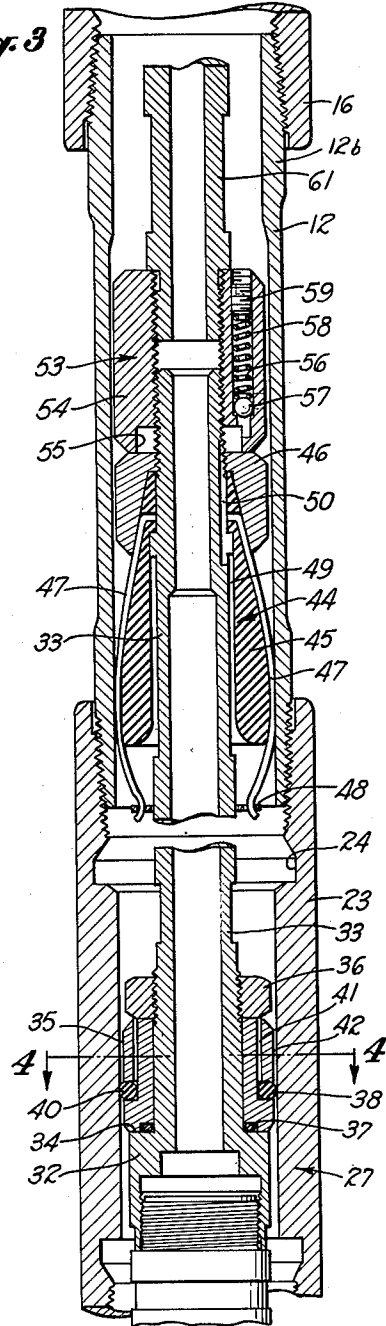


Fig. 3



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UNITED STATES PATENT OFFICE

2,568,320

FLUID-OPERATED PUMP SYSTEM WITH
PARALLEL TUBING

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19 Claims. (Cl. 103—46)

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This invention relates to fluid-operated deep well pumps and, more particularly, to a fluid-operated pump construction adapted to be dropped or pumped through a well tubing. The present invention comprises certain improvements on the type of fluid-operated well pump disclosed in my Patent No. 2,338,903, issued January 11, 1944, to which reference is hereby made for a statement of the general objects and advantages of such a device and for a description of the general method of operation thereof.

In general, the present invention relates to a well pumping system in which a pump tubing and a production tubing are set in a well, with a fluid-operated well pump adapted to be passed through the pump tubing to a seated pumping position adjacent the lower end thereof, the tubings being so connected relative to the pump that power oil, or other operating fluid, under high pressure is normally supplied through the pump tubing to operate the pump, the discharge from the pump being conveyed to the surface of the ground through the production tubing. The pump may be either dropped freely or pumped by the power oil through the pump tubing to pumping position and may be removed upwardly therethrough by circuiting the flow of power oil downwardly through the production tubing and upwardly through the pump tubing to pump the fluid-operated pump out of the pump tubing. This general system is shown and described in said Patent No. 2,338,903.

In order to utilize the power oil to pump the fluid-operated pump out of the pump tubing it, of course, necessary to maintain a fluid-tight seal between the pump and the inner wall of the tubing, and this is accomplished by providing suitable packing on or connected to the pump. The tighter the seal so formed between the pump and the pump tubing, the greater the friction therebetween during removal of the pump, and, of course, it is desirable to maintain this friction as low as possible to minimize wear on the packing and to minimize the power required to remove the pump. As such a fluid-operated pump is normally relatively light, it requires only a small upward pressure to lift the same if such friction is neglected. When the pump is seated in pumping position and during normal pumping operation, however, power oil under relatively high pressure is delivered downwardly through the pump tubing to operate the pump. Consequently, if only a light seal is formed between the pump and the pump tubing to facilitate removal of the pump by a reversed

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flow of power oil, such a seal will not withstand the downward fluid pressure in the pump tubing during normal pumping operation. It is, therefore, an object of the present invention to provide such a pump construction in which sealing means are provided between the pump and the pump tubing which will seal against a relatively high downwardly directed fluid pressure thereon, but which will seal against only a relatively low upwardly directed fluid pressure thereon. I prefer to accomplish this by providing one sealing means for sealing against such high fluid pressure, but which will be substantially inoperative to seal against an upwardly directed fluid pressure while the pump is passing upwardly through the pump tubing, and by providing a second sealing means which will be operative to seal against a relatively low upwardly directed fluid pressure while the pump is passing up through the pump tubing but which will be inoperative to seal against a high downwardly directed fluid pressure thereon, and this is a further object of the invention.

I prefer to provide such a high pressure seal in the form of a resilient O-ring which is carried in a suitable groove on the pump periphery and which is adapted for sealing engagement in a sealing collar provided on the pump tubing adjacent to the pump seat thereon, the internal diameter of the sealing collar being substantially less than the internal diameter of the pump tubing, and this is another object of the invention. In the use of such a construction, upon the application of fluid pressure below the O-ring there is a tendency for the O-ring to distort or blow out of its groove when it starts to register with a bore of a diameter larger than that of the collar, i. e., when the O-ring starts to pass out of the sealing collar. This commonly results in damage or breakage to the O-ring, which is undesirable. To obviate this difficulty, I prefer to incorporate a system of passages adapted to equalize the fluid pressures on opposite sides of the O-ring just before it registers with a bore portion of enlarged diameter, thus preventing blow-out of the ring, which is another object of my invention.

In pumping systems incorporating a pump of the character described above it is usual practice to use for the pump tubing a plurality of standard sections of tubing connected together by conventional tubing joints which normally leave a separation between the ends of adjacent tubing sections, which forms an annulus having a diameter substantially larger than the internal

diameter of the tubing. If a pump having a packing member thereon, which is adapted to form a fluid-tight seal between the pump and the interior of the pump tubing, is passed upwardly through the tubing by the application of fluid pressure below the packing member there is a tendency for the packing member to expand into each annulus as it registers therewith, and frequently the packing member jams in an annulus to prevent further upward movement of the pump through the tubing, which necessitates pulling the tubing to disconnect and free the pump therefrom. This is a very undesirable condition, and it is a further object of the present invention to provide means for minimizing this danger. Also, standard tubing joints are normally externally upset, and in the conventional process of making such tubing joints the internal diameter at the end thereof may be appreciably less than the internal diameter of the major portion of the length of the joint, and the packing member of the present invention tends to bind in such portions of smaller diameter. I prefer to remedy the foregoing difficulties by providing a pair of packer members carried by the pump and spaced longitudinally a distance greater than the width of any such annulus, the lower packer member normally bearing the lifting force of the fluid pressure therebelow but being provided with a by-pass passage means whereby in the event that the lower packer member becomes jammed in an annulus or in a tubing portion of reduced diameter excess fluid pressure is by-passed past the lower packer member and applied to the upper packer member, to exert a pulling force on the lower packer tending to free it from its jammed condition. This is also an object of the invention, and substantially minimizes the tendency of the pump to jam or stick in the tubing during the time that it is being pumped out by the application of fluid pressure to the lower end thereof.

Other objects and advantages of the invention reside in the specific arrangements of parts and passages, and other features, more fully described in the following specification and shown in the drawings, in which:

Fig. 1 is a utility view, partly in longitudinal section, showing the invention installed in a well during normal pumping operation;

Fig. 2 is an enlarged longitudinal sectional view of the upper end of the nose assembly of the pump;

Fig. 3 is a downward continuation of Fig. 2;

Fig. 4 is a cross-sectional view taken on the line 4—4 of Fig. 3;

Fig. 5 is a longitudinal sectional view of an alternative embodiment of one feature of the invention; and

Fig. 6 is a cross-sectional view taken on the line 6—6 of Fig. 5.

Referring to the drawing, Fig. 1 shows a well casing 10 provided with a casing head 11 from which is suspended a pump tubing 12 and a production tubing 13. The tubings 12 and 13 are, of course, made up of a number of sections connected together by suitable tubing joints, one such tubing joint 16 being illustrated. The tubing joint 16, as shown, is the conventional externally upset type, in which the internal diameter of the joint at each end opposite the upset portions thereof is usually appreciably less than the internal diameter of the major portion of the joint, such small diameter portions being indicated by the numerals 12a and 12b

in Figs. 2 and 3, respectively. To the upper ends of the pump tubing 12 and production tubing 13 are connected upwardly extending subs 14 and 15, respectively, to the upper ends of which is connected a valve mechanism 17, to which in turn is connected a power oil inlet pipe 18 and a discharge pipe 19. The power oil inlet pipe 18 is connected in turn to a suitable high pressure fluid pump 20, preferably of the triplex type, and the discharge pipe 19 is connected to a suitable point of disposal or use (not shown). The valve mechanism 17 may be of any suitable type and as shown is a four-way valve construction adapted to be operated by a hand lever 21 so that the inlet pipe 18 may be connected with the sub 14 or the sub 15, and, alternatively the discharge pipe 19 may be connected with the sub 15 or the sub 14.

As best illustrated in Figs. 1 and 3, to the lower end of the pump tubing 12 is connected a sealing collar 23, which is tubular in form, and to the lower end of the sealing collar is in turn connected a foot assembly 25 provided with a conical seat 26 on which is seated a standing valve assembly 28 which carries a fluid-operated pump 27. As will be understood, the lower end of the production tubing 13 is also connected to the foot assembly 25. The fluid-operated pump 27 may be of any conventional type, and the standing valve assembly 28 is adapted to receive well fluid from the well in which the casing 10 is set through a conventional type of gas anchor 29 and deliver such fluid to the pump. The fluid-operated pump 27 is also provided with a nose assembly 30 which is connected to the upper end of the pump and extends upwardly therefrom. The fluid-operated pump 27 is of an external diameter such that it may be readily passed through the pump tubing 12 to and from the position illustrated in Fig. 1, which is the normal pumping position of the unit.

As illustrated in Figs. 2 and 3, the lower end of the nose assembly 30 includes a lower tubular element 32 which is threaded to the upper end of the fluid-operated pump 27, and which is provided with an upwardly extending tubular extension 33, the juncture of the tubular element and the extension forming an annular shoulder 34 on which rests an annular collar 35, the collar being held rigidly in engagement with the shoulder by a nut 36 threaded on the extension. A resilient packing ring 37 is clamped between the collar 35 and the shoulder 34 to provide a fluid-tight seal therebetween. The collar 35 is also provided with an annular groove 38 in which is disposed an annular, resilient O-ring 40, of conventional construction. Communicating between the upper side of the annular groove 38 and the upper end of the collar 35 are a plurality of circumferentially spaced longitudinal ports 41, which provide open fluid communication between the upper portion of the groove, behind the O-ring 40, and the space above the collar 35, for a purpose to be described hereinafter. The outside diameter of the collar 35 is only slightly less than the internal diameter of the sealing collar 23 so as to provide a small clearance 42 therebetween. The cross-sectional area of the clearance 42 is substantially less than the total cross-sectional area of all of the ports 41. The resilient packing ring 40 and its assembly may be referred to as a high pressure packer means, as it is designed to provide a fluid seal between the fluid-operated pump and the bore of the sealing collar 23 when the fluid-operated

pump is in its normal pumping position illustrated in Fig. 1 against relatively high fluid pressures existing in the pump tubing 12 and in the collar 23 above the O-ring 40 during pumping, as will be explained hereinafter.

Carried on, and adjacent the upper end of, the tubular extension 33 is a first low pressure packer means 44. The low pressure packer means 44 includes a generally tubularly shaped resilient packer element 45, the lower end of which is adapted to form a fluid-tight low pressure seal with the inner wall of the pump tubing 12, and the upper end of which is clamped to the tubular extension 33 by a nut 46 threaded on the upper end of the tubular extension, the packer means 44 also including spring arms 47 the lower ends of which are retained in a washer 48, the spring arms being adapted to hold the packer element and assist in preventing the packer from expanding into recesses in the collars 16. As will be noted, the interior of the packer element 45 for the greater part of its length is spaced from the periphery of the tubular sleeve 33 so as to provide an annular fluid passage 49 therebetween which communicates with a vertical groove 50 formed in the tubular extension so as to provide fluid communication between the annular fluid passage and an annular recess 55.

Also threaded on the upper end of the tubular sleeve 33 is a by-pass means 53, which includes a collar 54, provided with the annular recess 55 in its lower end with which communicates a longitudinal bore 56 containing a ball-check valve member 57 normally retained in a downwardly seated closed position, as illustrated in Fig. 3, by a compression spring 58 which engages a spider 59 threaded into the upper end of the bore 56.

The collar 54 has threaded into its upper end an upper tubular element 61 which, as best shown in Fig. 2, carries thereon a second low pressure packing means 62 which is generally similar to the first low pressure packer means 44. As will be noted, in the second low pressure packing means 62 there are no groove or slots similar to the vertical groove in the first packer means 44. Threaded onto the upper end of the upper tubular element 61 is an inlet member 63 which is provided with circumferentially spaced radial ports 64 adapted to permit power oil, or other operating fluid, to enter and flow through the nose assembly 30 to the fluid-operated pump 27 from the pump tubing 12.

In Figs. 5 and 6, a modified form of sealing collar 66 is illustrated which is adapted to be substituted for the sealing collar 23 illustrated in Fig. 3 if desired. In this form, circumferentially spaced radial ports 67 are provided and communicate with longitudinal ports 68, and an annular collar 69 is provided on the nose assembly of the pump, the collar 69 being similar in all respects to the collar 35 illustrated in Fig. 3 except that it does not have any passages or ports similar to the ports 41 illustrated in Fig. 3. The collar 69 is spaced slightly from the wall of the bore of the sealing collar 66 to provide a clearance 70 therebetween, and the radial ports 67 are designed so that their total cross-sectional area is greater than the cross-sectional area of the clearance 70, for a purpose to be described hereinafter.

In installation, for normal pumping operation, the unit is assembled as illustrated in Fig. 1. The fluid-operated pump 27 may be disposed in its pumping position as illustrated in Fig. 1 be-

fore the pump tubing 12 is run into the well, so that the pump is run in with the pump tubing, or, alternatively, the pump tubing 12 and production tubing 13 may be run into the well to the positions illustrated in Fig. 1 without the pump, and the pump may then be dropped by gravity through the pump tubing to the pumping position as illustrated. The manner in which the fluid-operated pump 27 is inserted into the upper end of the pump tubing 12 through the valve mechanism 17, or removed therefrom, is no part of the present invention, but is fully disclosed and described in said Patent No. 2,338,903, to which reference is made. Preferably, however, the fluid-operated pump 27 is pumped downwardly through the pump tubing 12 to the seated position illustrated in Fig. 1, by actuating the high pressure or triplex pump 20 to force power oil, or other operating fluid, under high pressure through the pipe 18, the valve mechanism 17, and the sub 14 into the pump tubing 12 to cause the fluid-operated pump 27 to pass rapidly downwardly through the pump tubing. When the fluid-operated pump 27 seats on the standing valve assembly 28, in the pumping position illustrated in Fig. 1, the power oil delivered by the high pressure pump 20 through the pump tubing 12 will enter the nose assembly 30 through the radial ports 64 and pass downwardly through the nose assembly to the fluid-operated pump to actuate the same. As will also be understood, operation of the fluid-operated pump 27 will draw well fluid from the casing 10 through the gas anchor 29 and upwardly through the standing valve assembly 28 into the fluid-operated pump, from which it is discharged into the production tubing 13 and is conveyed upwardly there-through, through the sub 15 and the valve mechanism 17 into the discharge pipe 19 through which it flows to storage or disposal. During normal pumping operation, the high pressure power oil in the pump tubing 12 readily passes downwardly past the packer means 62 and 44 and exerts a high pressure on the resilient O-ring 40. The O-ring 40, however, provides a fluid-tight seal between the fluid-operated pump 27 and the inner wall of the sealing collar 23 withstanding the operating pressure of the power oil.

When it is desired to remove the fluid-operated pump 27 from the well through the pump tubing 12, the handle 21 of the valve mechanism 17 is operated to provide fluid communication between the sub 14 and the discharge pipe 19, and to provide fluid communication between the sub 15 and the power oil inlet pipe 18. Power oil is then conveyed by the high pressure pump 20 downwardly through the sub 15 and the production tubing 13 to the lower end of the fluid-operated pump 27 to exert an upward force on the pump causing it to move upwardly out of the sealing collar 23 and then upwardly through the pump tubing 12. Power oil trapped above the pump 27 in the pump tubing 12, during removal of the pump, can, of course, exhaust through the discharge pipe 19. When the power oil is first admitted below the fluid-operated pump 27 to remove the same, the fluid pressure of the power oil is imposed on the O-ring 40, and the pump starts to move upwardly out of the sealing collar 23. As soon as the O-ring 40 starts to register with the annular cavity 24 in the upper end of the sealing collar 23 and starts to expand into the cavity, communication is established between the power oil in the clearance 42 and the

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vertical port 41 so as to equalize the fluid pressures on both sides of the O-ring, which keeps it from being blown out by a fluid pressure differential into the cavity 24. In the absence of the longitudinal ports 41, it has been my experience that the O-ring 40 is frequently blown out into the cavity 24 and damaged or completely lost, requiring its replacement, which difficulty is obviated by provision of the ports. By making the total cross-sectional area of the ports 41 greater than the cross-sectional area of the clearance 42, as soon as communication is provided between the ports 41 and the clearance below the O-ring, the fluid pressures are equalized, and can never rise higher on the inside of the O-ring than the fluid pressure at the downstream end of the clearance 42. This is a valuable protective feature of the invention.

As soon as communication is provided between the clearance 42 below the O-ring 40 and the longitudinal ports 41, power oil, of course, passes upwardly to the lower end of the first low pressure packer means 44, to impose an upward lifting force thereon, the normal lifting pressure of the power oil being confined to application below the first low pressure packer means 44 by the action of the compression spring 58 maintaining the ball-check valve member 57 seated as shown in Fig. 3. Consequently, the full lifting force of the power oil is exerted on the first low pressure packer means 44 during a normal run-out operation. In this connection, it is to be noted that the internal diameter of the sealing collar 23 is substantially less than the internal diameter of the power tubing 12 and, consequently, after the O-ring 40 passes out of the bore of the sealing collar the O-ring is not effective to form a seal between the fluid-operated pump 27 and the interior of the tubing 12. Thus, the full lifting force of the power oil is carried by the first low pressure packer means 44. In the event that the first low pressure packer means 44 expands into a cavity 24 between adjacent tubing sections in a tubing joint 16 or binds in a reduced diameter portion 12a or 12b of the tubing 12, as sometimes occur, the same may jam therein tending to restrict further upward movement of the fluid-operated pump. When this occurs, of course, fluid pressure below the packer means 44 immediately starts to rise and, if allowed to rise unchecked, might rise to a value sufficient to seriously damage the packer means 44. However, any substantial rise of fluid pressure of the power oil below the packer means 44 is relieved by the opening of the ball-check valve 57 and excess fluid may then flow upwardly to exert a lifting force on the lower end of the second low pressure packer means 62 which, if the first packer means 44 is stuck between tubing sections in a tubing joint 16 or in the reduced diameter portions 12a or 12b, will be in a smooth portion of one of the tubing sections, as illustrated in Fig. 2. Consequently, in such case, the full pressure of the power oil is applied to the lower end of the second packer means 62, which continues the upward movement of fluid-operated pump 27 through the pump tubing, and frees the first packer means 44 from any stuck condition which it may encounter between tubing sections by exerting a pull on the first packer means 44, and such pull on the resilient packer element 45 tends to contract and free it. As soon as the first packer means 44 passes back into one of the tubing sections the full pressure of the power oil can then be applied on the bottom

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thereof, and it then carries the lifting load imposed by the power oil thereon until such time as the pressure of the power oil therebelow again rises due to further sticking of the first packer means in a tubing joint or otherwise.

The alternative embodiment of the sealing collar 66, illustrated in Figs. 5 and 6, operates substantially the same as the embodiment illustrated in Figs. 1 to 4. The principal difference is that in the embodiment illustrated in Figs. 1 to 4 the pressure equalizing ports 41 are carried by the pump assembly, whereas in Figs. 5 and 6 the ports 67 and 68 are provided in the sealing collar itself. In the operation of the embodiment illustrated in Fig. 5, as soon as the annular collar 69 moves upwardly to a point at which the resilient O-ring 71 passes over the radial ports 67, fluid communication is provided between the clearance 70 and the space above the sealing collar so as to equalize the fluid pressures on the O-ring 71.

From the foregoing description, it will be understood that the O-ring 40 and its cooperating parts provide a high pressure fluid seal, adapted to, in effect, seal between the fluid-operated pump 27 and the pump tubing 12 during normal operation of the pump, and that the packer means 44 and 62 provide a low pressure fluid sealing means adapted to form, in effect, a fluid-tight seal between the fluid-operated pump and the interior of the pump tubing while the pump is being passed upwardly through the tubing. It will also be understood that the provision of the dual low pressure packers 44 and 62, spaced apart a distance greater than the width of the tubing joint 16, is a further feature of the invention, together with the by-pass means 53 operating in conjunction with the packers.

Although I have shown and described a preferred embodiment of the invention, with a preferred modification thereof, it will be understood that this is merely illustrative, and that I do not intend to be confined thereto, but desire to be afforded the full scope of the following claims.

I claim as my invention:

1. In a fluid-operated pumping device, the combination of: a pump tubing; a fluid-operated pump adapted to be passed through said tubing; first sealing means associated with said pump and adapted to form a fluid-tight seal between said pump and said tubing during passage of said pump upwardly through said tubing; by-pass means adapted to open upwardly to relieve excessive fluid pressure on the lower side of said first sealing means; and second sealing means associated with said pump above said first sealing means and adapted to form a fluid-tight seal between said pump and said tubing during passage of said pump upwardly through said tubing.

2. In a fluid-operated pumping device, the combination of: a pump tubing comprised of a plurality of sections of tubing, adjacent sections being connected together by tubing collars; a fluid-operated pump adapted to be passed through said tubing; first sealing means associated with said pump and adapted to form a first fluid-tight seal between said pump and said tubing during passage of said pump through said tubing; second sealing means associated with said pump and adapted to form a second fluid-tight seal between said pump and said tubing during passage of said pump through said tubing, said first and second sealing means being longitudinally spaced apart a distance greater than the

space between adjacent ends of uniform sections of said tubing sections in said tubing collars; and by-pass means adapted to open upwardly to relieve excess fluid pressure on the lower side of the lowermost of said sealing means.

3. In a fluid-operated pumping device, the combination of: a pump tubing having means forming a pump seat adjacent its lower end; a sealing collar secured relative to said pump tubing and adjacent said seat; a fluid-operated pump adapted to be passed downwardly through said tubing to seat on said seat and to enter said sealing collar; first sealing means disposed between said pump and said collar when said pump is seated on said seat to form a fluid-tight seal between said pump and said collar; second sealing means disposed on said pump and adapted to form a fluid-tight seal between said pump and said tubing during passage of said pump upwardly through said tubing, said second sealing means including a pair of longitudinally spaced sealing elements; and means for applying fluid pressure to the lower side of the uppermost of said sealing elements whenever the fluid pressure applied to the lower side of the lowermost of said sealing elements becomes excessive.

4. In a fluid-operated pumping device, the combination of: a pump tubing having means forming a pump seat adjacent its lower end; a sealing collar secured relative to said pump tubing and adjacent said seat; a fluid-operated pump adapted to be passed downwardly through said tubing to seat on said seat and to enter said sealing collar; first sealing means disposed between said pump and said collar when said pump is seated on said seat to form a fluid-tight seal between said pump and said collar; and second sealing means disposed on said pump and adapted to form a fluid-tight seal between said pump and said tubing during passage of said pump upwardly through said tubing, said second sealing means including a pair of longitudinally spaced sealing elements, the lowermost of said elements being provided with by-pass means adapted to relieve excessive fluid pressure on the lower side of said lowermost element.

5. In a fluid-operated pumping device, the combination of: tubular sealing collar means providing an annular sealing bore and a cavity of larger internal diameter than said bore; a fluid-operated pump adapted to be passed into said bore; a resilient O-ring carried by said pump and adapted to form a fluid-tight seal between said pump and said bore when said O-ring registers with said bore; and means for substantially equalizing the fluid pressures above and below said O-ring during relative movement between said pump and said collar and when said O-ring registers with said cavity.

6. In a fluid-operated pumping device, the combination of: tubular sealing collar means providing an annular sealing bore and a cavity of larger internal diameter than said bore; a fluid-operated pump adapted to be passed into said bore; a resilient O-ring carried by said pump and adapted to form a fluid-tight seal between said pump and said bore when said O-ring registers with said bore; and means associated with said pump for substantially equalizing the fluid pressure above and below said O-ring during relative movement between said pump and said collar and when said O-ring registers with said cavity.

7. In a fluid-operated pumping device, the combination of: tubular sealing collar means pro-

viding an annular sealing bore and a cavity of larger internal diameter than said bore; a fluid-operated pump adapted to be passed into said bore; a resilient O-ring carried by said pump and adapted to form a fluid-tight seal between said pump and said bore when said O-ring registers with said bore; and means associated with said collar for substantially equalizing the fluid pressures above and below said O-ring during relative movement between said pump and said collar and when said O-ring registers with said cavity.

8. In a device of the character described, the combination of: an element having a tubular bore and having a cavity at one end of and of larger diameter than said bore; a cylindrical member in said bore and axially movable relative thereto; a resilient O-ring carried by said member and adapted to provide a fluid-tight seal between said member and said bore; and means for substantially equalizing the fluid pressures on each side of said O-ring during relative movement between said member and said bore and when said O-ring registers with said cavity.

9. In a device of the character described, the combination of: an element having a tubular bore and having a cavity at one end of and of larger diameter than said bore; a cylindrical member in said bore and axially movable relative thereto; a resilient O-ring carried by said member and adapted to provide a fluid-tight seal between said member and said bore; and means associated with said member for substantially equalizing the fluid pressures on each side of said O-ring during relative movement between said member and said bore and when said O-ring registers with said cavity.

10. In a device of the character described, the combination of: an element having a tubular bore and having a cavity at one end of and of larger diameter than said bore; a cylindrical member in said bore and axially movable relative thereto; a resilient O-ring carried by said member and adapted to provide a fluid-tight seal between said member and said bore; and means associated with said element for substantially equalizing the fluid pressure on each side of said O-ring during relative movement between said member and said bore and when said O-ring registers with said cavity.

11. In a device of the character described, the combination of: an element having a tubular bore and having a cavity at one end of and of larger diameter than said bore; a cylindrical member in said bore and axially movable relative thereto; a resilient O-ring carried by said member and adapted to provide a fluid-tight seal between said member and said bore; and passage means communicating between one side of said O-ring and said cavity, the cross-sectional area of said passage means being greater than the cross-sectional area of the clearance between said member and said bore.

12. In a device of the character described, the combination of: an element having a tubular bore and having a cavity at one end of and of larger diameter than said bore; a cylindrical member in said bore and axially movable relative thereto and providing an annular clearance therebetween; a resilient O-ring carried by said member and adapted to provide a fluid-tight seal between said member and said bore; and passage means communicating between one side of said O-ring and said cavity, the cross-sectional area and length of said passage means

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being such that the fluid pressure drop there-through is substantially less than that in said clearance.

13. In a sealing device, the combination of: a first member having a bore and having an opening in the wall of said bore; a cylindrical second member in said bore and axially movable relative thereto; a resilient O-ring carried by said second member and adapted to provide a fluid-tight seal between said second member and the wall of said bore, said first member and said second member being relatively movable so as to move said O-ring past said opening, there normally being a fluid-pressure differential across said O-ring in the direction of said opening; and passage means in one of said members adapted to relieve said fluid-pressure differential across said O-ring at least as soon as said O-ring starts to register with said opening.

14. In a sealing device, the combination of: a first member having a bore and having an opening in the wall of said bore; a cylindrical second member in said bore and axially movable relative thereto; a resilient O-ring carried by said second member and adapted to provide a fluid-tight seal between said second member and the wall of said bore, said first member and said second member being relatively movable so as to move said O-ring past said opening, there normally being a fluid-pressure differential across said O-ring in the direction of said opening; and passage means in one of said members adapted to relieve said fluid-pressure differential across said O-ring at least as soon as said O-ring starts to register with said opening, the cross-sectional area of said passage means being greater than the cross sectional area of the clearance between said second member and said bore.

15. In a sealing device, the combination of: a first member having a bore and having an opening in the wall of said bore; a cylindrical second member in said bore and axially movable relative thereto; a resilient O-ring carried by said second member and adapted to provide a fluid-tight seal between said second member and the wall of said bore, said first member and said second member being relatively movable so as to move said O-ring past said opening, there normally being a fluid-pressure differential across said O-ring in the direction of said opening; and passage means in said second member adapted to relieve said fluid-pressure differential across said O-ring at least as soon as said O-ring starts to register with said opening, the cross-sectional area of said passage means being greater than the cross-sectional area of the clearance between said second member and said bore.

16. In a sealing device, the combination of: a first member having a bore and having an opening in the wall of said bore; a cylindrical second member in said bore and axially movable relative thereto; a resilient O-ring carried in an annular groove in said second member and adapted to provide a fluid-tight seal between said sec-

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ond member and the wall of said bore, said first member and said second member being relatively movable so as to move said O-ring past said opening, there normally being a fluid-pressure differential across said O-ring in the direction of said opening; and passage means in said second member communicating between the inner wall of said groove and the exterior of said second member at a point between said groove and said opening and adapted to relieve said fluid-pressure differential across said O-ring at least as soon as said O-ring starts to register with said opening, the cross-sectional area of said passage means being greater than the cross-sectional area of the clearance between said second member and said bore.

17. In a sealing device, the combination of: a first member having a bore therein and having an opening in the wall of said bore; a cylindrical second member in and movable axially relative to said bore there being a clearance between said second member and the wall of said bore; an annular sealing element in an annular groove in said second member and adapted to provide a fluid-tight seal between said second member and the wall of said bore, said sealing element registering with said opening during movement of said second member relative to said bore; and passage means in one of said members for connecting said clearance on one side of said sealing element in fluid communication with the interior of said bore on the opposite side of said sealing element during movement of said sealing element toward said opening and before said sealing element fully registers with said opening.

18. A sealing device according to claim 17 wherein said passage means includes a passage in said second member which communicates at one end with the interior of said bore on said opposite side of said sealing element and which communicates at its other end with said annular groove.

19. A sealing device according to claim 17 wherein said passage means includes a passage in said first member which communicates at its ends with the interior of said bore, one end of said passage being spaced from said opening so that said passage connects said clearance in fluid communication with the interior of said bore at least as soon as said sealing element begins to register with said bore.

CLARENCE J. COBERLY.

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