

Jan. 6, 1942.

C. J. COBERLY

2,268,543

METHOD OF ASSEMBLING FLUID OPERATED PUMPS

Original Filed July 18, 1932

2 Sheets-Sheet 1

Fig. 1.

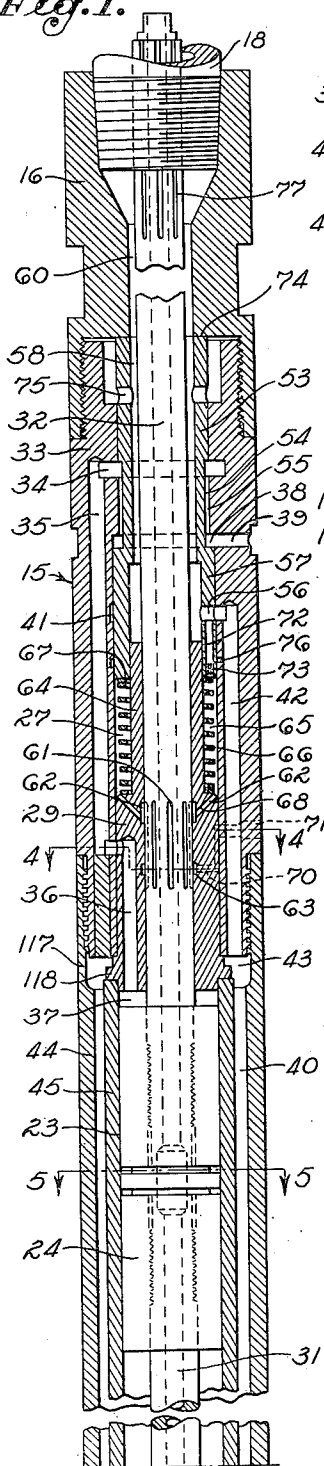


Fig. 2.

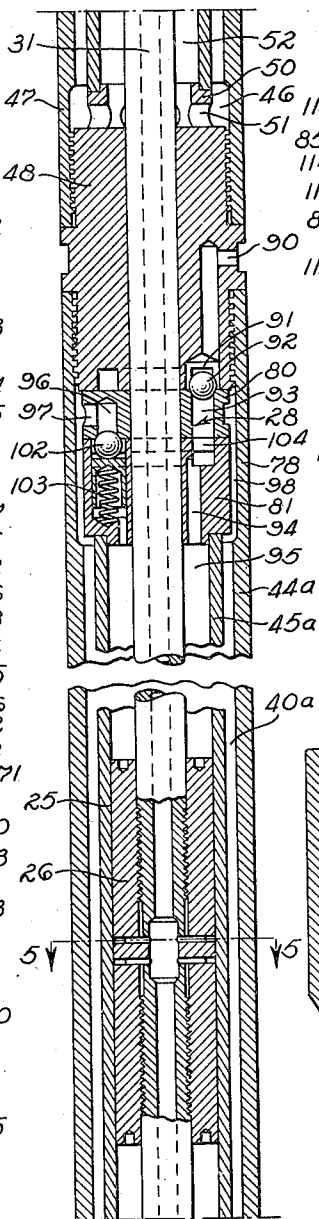
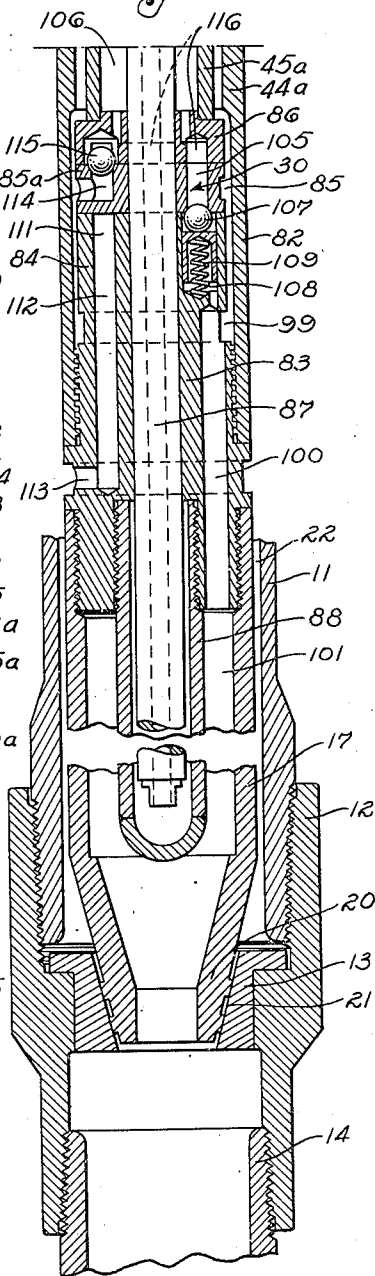


Fig. 3.



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2 Sheets-Sheet 2

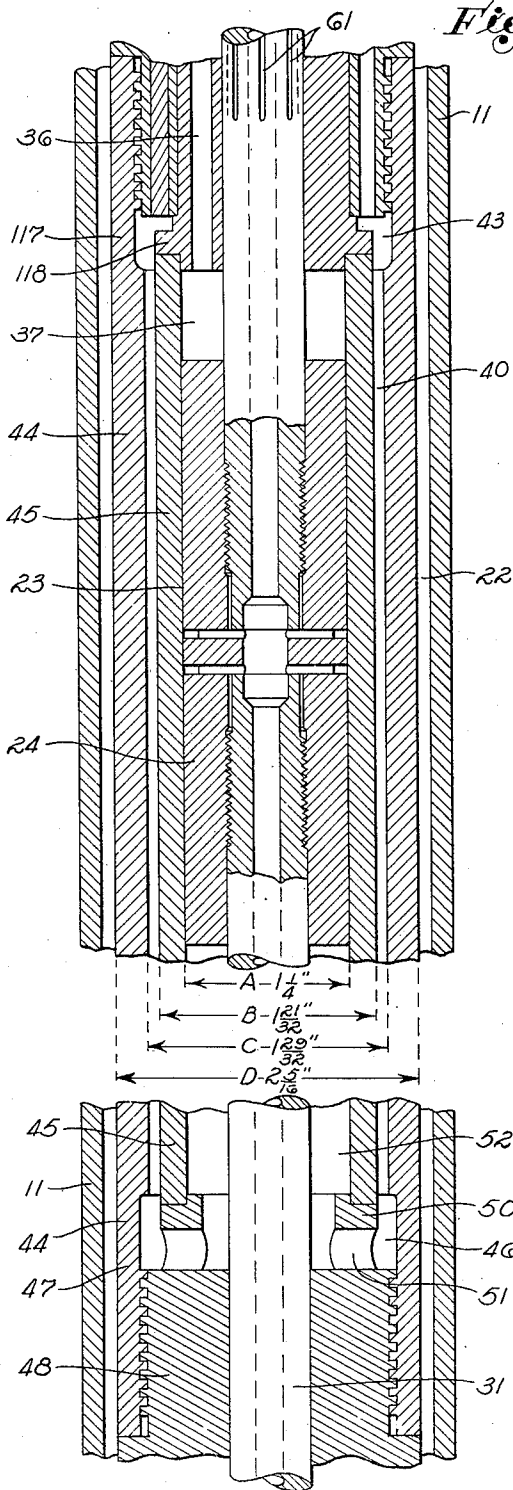


Fig. 6.

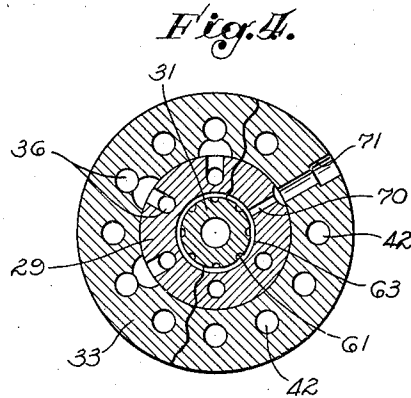


Fig. 4.

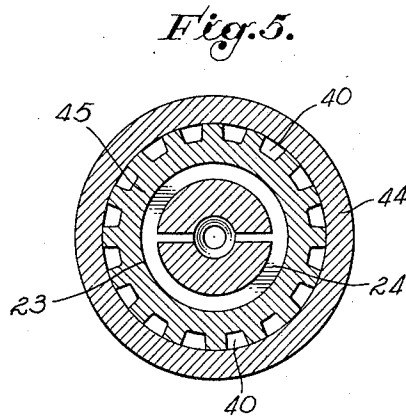


Fig. 5.

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UNITED STATES PATENT OFFICE

2,268,543

METHOD OF ASSEMBLING FLUID
OPERATED PUMPS

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of Nevada

Original applications July 18, 1932, Serial No.
623,171, and April 11, 1934, Serial No. 720,056.
Divided and this application January 24, 1938,
Serial No. 186,596

5 Claims. (Cl. 29—84)

My invention relates in general to means for connecting together cooperating parts which are to be subjected to fluid pressure, and relates in particular to the construction of high pressure pumps for operation in spaces of limited size. The present principal application of my invention is to fluid operated pumps intended for use in deep wells for the purpose of pumping fluid from such wells, and accordingly the following disclosure, although it relates to the general application of the invention, is directed specifically to a use in which the features and value thereof have been proved, namely, pumps for pumping oil from deep wells from which it is difficult to pump the fluid by use of the conventional sucker rod operated pumps. This application constitutes a division of my application, Serial No. 623,171, for Liquid operated pump, filed July 18, 1932, on which Letters Patent No. 2,081,220 issued on May 25, 1937, and is a division of my copending application, Serial No. 720,056, for Method of assembling elements of liquid operated motor, filed April 11, 1934.

The idea of operating a pump in a well by the use of liquid constitutes a subject matter to which many inventors have directed their attention, it being recognized that great power losses, as well as other difficulties, result where the pump is operated in the well by the use of a string of sucker rods. These liquid or fluid operated pumps may be broadly divided into two classes, namely, the alternating type in which the actuation of the pump is accomplished by variations in the pressure and movement of the actuating fluid so that it alternately flows up and down through the supply pipe leading to the pump, and the direct type in which the actuating fluid in the supply pipe flows constantly in one direction and is maintained under a more or less constant pressure. My invention is of such character that it may be employed in either of the foregoing types of pumps, since the invention relates to cooperating parts and means for assembling the same.

It is an object of my invention to provide a pump structure which may be made in very small sizes so that it may be employed in the small pipes or casings which must be used at the lower ends of deep wells owing to the restrictions in pipe or casing sizes resulting from our present methods of well drilling.

It is a further object of the invention to provide a pump of this character in which the losses due to leakage, and also losses due to friction, are maintained at a minimum. For exam-

ple, fluid operated pumps in deep wells as a general rule require high fluid pressures. In a well of 10,000 feet depth the pressure in the lower end of the power fluid supply pipe and in the power cylinder may often be between 4,000 and 4,500 pounds per square inch. The result of this is that various parts exposed to this pressure are deformed by the heavy stresses exerted therein to the extent that the operating relation of cooperating parts is changed. For example, an inserted liner, either around a piston rod or a pump piston, may be contracted or constricted to somewhat smaller size by the action of high fluid pressure, with the result that it is caused to bear with heavy friction against its cooperating part, thereby introducing frictional losses into the operation of the pump. Also, certain tubular parts of a pump of the general character herein discussed will be alternately placed under external and internal fluid pressures so that during one part of the operation of the pump such a part frictionally engages the part with which it cooperates, and during another part of the operation of the pump is expanded to the extent that a material leakage therethrough occurs, both conditions of operation resulting in a loss of efficiency.

It is accordingly an object of my invention to provide in a high pressure fluid operated pump a method and means for placing such parts as hereinabove described under such initial stress at the time of assembling the parts that the high fluid pressures acting thereagainst will not deform the parts to an extent causing friction or leakage losses. In pumps of the general character herein treated, the fluid pressures in the chambers of such pumps increase in direct proportion to the depth of the well, and accordingly it is found that a pump which will operate satisfactorily at a depth of several thousand feet will refuse to operate at twice such depth or will show a very great loss in efficiency at increased depths. Pumps embodying the principles of my present invention are found to operate freely and without material change in efficiency at depths ranging from minimum to maximum.

A further object of the invention is to provide a simple and effective means and method for securing cooperative pump parts together in fluid-tight relation and in such a manner that the parts may be contained and operated within minimum space limits.

Further objects and advantages of the invention will be made evident throughout the following part of the specification.

Referring to the drawings, which are for illustrative purposes only,

Fig. 1 is a vertically sectioned view of the upper portion of a pump embodying my invention.

Fig. 2 is a vertically sectioned view of the central portion of the pump, this view showing the part of the pump structure connecting to the lower end of Fig. 1.

Fig. 3 is a vertically sectioned view of the lower end of the pump, this view showing the part of the pump connected to the lower end of Fig. 2.

Fig. 4 is an enlarged cross section taken as indicated by the line 4-4 of Fig. 1.

Fig. 5 is an enlarged cross-sectional view on the plane indicated by the lines 5-5 of Figs. 1 and 2.

Fig. 6 is an enlarged, vertically sectioned view showing the upper cylinder and piston structure constituting the fluid motor of the pump structure.

The pump embodying my invention employs a string of piping 11 which extends from the top of a well down into the body of oil in the producing zone thereof. This piping 11 constitutes a means for carrying pumped oil to the top of the well, and since its use is well known and contributes only indirectly to the present invention, such piping 11 has been shown only in Figs. 3 and 6. At the lower end of the pipe 11 a fitting 12 is secured which carries a seat member 13 therein which has a pipe 14 extending downwardly therefrom. The pump proper 15 includes all of the parts between the upper fitting 16 of Fig. 1 and the foot fitting 17 of Fig. 3 and is permanently connected to a pressure pipe 18, Fig. 1, by means of which it is lowered into the pipe string 11 to such a position that the lower tapered end 20 of the foot fitting 17 will engage the conical seat 21 of the seat member 13. Fluid under pressure, such as oil, is forced downwardly through the pressure pipe 18 to the upper or inlet end of the pump 15. After this fluid has operated within the pump 15 to actuate the same, it is discharged into the space 22 within the piping 11, which space 22 also receives the oil pumped from the well, the pumped oil and the discharge of actuating oil combining in the space 22 and passing upwardly through the piping 11 to the top of the well, where it is carried off through a suitable discharge or production piping system.

The pump includes a power cylinder 23 having a power piston 24 therein, a pumping cylinder 25 having a pumping piston 26 therein, valve means 27 for feeding a fluid under pressure to the power cylinder 23 in a desired timed relation, and check valve means 28 and 30 disposed at the upper and lower ends of the pumping cylinder 25 for controlling the intake and discharge of the pumped oil therefrom. The pistons 24 and 26 are connected by means of a hollow rod 31, and upwardly from the power piston 24 a hollow pilot rod 32 extends through the valve means 27, this pilot rod 32 moving upward and downward with the power piston 24 and serving as a control for the valve means, as will be hereinafter described. Threaded to the lower end of the upper fitting 16 is a valve fitting 33 having internal ports 34 which communicate, through a passage 35 in the valve fitting and through an opening 36 in a valve liner 29 of tubular form which is held within the valve fitting 33, with the upper space 37 of the power

cylinder 23. Below the ports 34 is a discharge port 38 which communicates through a radial passage 39 with the exterior of the valve fitting 33 so as to deliver discharge fluid into the space 22 within the piping 11. Spaced below the discharge port 38 are ports 41 which connect through a vertical passage 42 with an annular space 43 at the lower end of the valve fitting 33.

As shown in Fig. 5, the power cylinder 23 comprises a tubular or cylindrical shell 44 and a liner 45 therein, there being vertical passages 40 between the shell 44 and the liner 45 connecting the space 43 of Fig. 1 with a space 46 formed near the lower end of the shell 44 and adjacent the lower end of the liner 45. The passages 40 may be formed by cutting longitudinal grooves either in the shell 44 or on the exterior of the liner 45, but preferably the passages 40 constitute grooves cut in the external portion of the liner 45, as shown in Fig. 5. The shell has a wall 47 which projects downwardly beyond the lower end of the liner 45 and is threaded to receive the upper end of an intermediate connector body 48 having a wall 50 projecting upwardly therefrom into shouldered engagement with the lower end of the liner 45, such wall 50 having radial openings 51 therein through which the space 46 is connected with the lower cylinder space 52 within the liner 45 below the piston 24.

In Fig. 1 a tubular valve member 53 is shown in raised position in the bore of the valve fitting 33 so that a flat peripheral depression or channel 54 in the external face of the valve member 53 will form an annular space 55 connecting the upper cylinder space 37, through the passage 36, the passage 35, and the ports 34, with the discharge passage 39. In this position of the valve member 53, ports 56 in the lower wall 57 thereof connect the passage 42 leading from the lower cylinder space 52 with the annular space 58 within the valve member 53 and around the pilot rod 32, which annular space is fed with high pressure fluid which has been delivered from the top of the well through the pressure pipe 18 to the bore 60 of the upper fitting 16. Accordingly, at this time the high pressure operating fluid is applied through the ports and passages above described to the lower cylinder space 52, and the pressure of such fluid is exerted against the lower end of the power piston 24; and for the purpose of explanation of the operation of the pump, it may be assumed that such fluid pressure has moved the piston 24 through its upward stroke into its top position, as shown in Fig. 1, the pilot rod 32 being also in its uppermost position so that longitudinal passages 61 therein will interconnect ports 62 and 63 of channel form in the inner face of the valve liner 29 which has an upwardly extending tubular portion 64 which projects into the lower end of the valve member 53 and around which a pressure chamber 65 is formed below the lower tubular wall member 57 of the valve member 53, such chamber having a spring 66 exerting a lifting pressure against the lower face 67 of the valve member 53. The port 62 is connected through diagonal passages 68 with the pressure chamber 65, and the port 63 connects through a passage 70 in the valve liner 29 and a passage 71 in the valve fitting 33 with the space 22 exterior of the pump 15 within the piping 11 through which fluid is discharged to the top of the well.

Before the upward movement of the passages 61 on the pilot rod 32 into the position of coop-

eration with the ports 62 and 63, the pressure chamber 65 is held under fluid pressure equal to the pressure in the space 58, through a passage 72 which leads downwardly in the lower wall 57 of the valve member 53 from the port 56, this passage having an orifice member 73 therein for restricting the flow of fluid through the passage 72 to a small quantity. When the passages 61 of the pilot rod 32 are moved into the position in which they are shown in Fig. 1, the pressure chamber 65 is connected to the discharge space 22, thereby relieving the pressure in the pressure chamber 65, whereupon the fluid pressure acting against the upper end face 74 of the valve member 53 will cause the valve member 53 to move downwardly from the position in which it is shown to a position in which radial ports 75 therein are brought into conjunction with the ports 34, and the external channel 54 will be moved down to a position in which it will connect the ports 38 and 41, so that the discharge passage 39 is connected to the passage 42 through which communication is made with the vertical passages 40 which in turn communicate with the lower cylinder space 52. Accordingly, when the valve member 53 is thus moved to lowered position so that the lower end space 52 of the cylinder will be connected to discharge instead of to pressure, the upper space 37 of the cylinder will be fed with fluid under pressure from the annular space 58 through the ports 75 and 34 and the passages 35 and 36, thereby reversing the direction of movement of the power piston 24 from upward to downward. Also, at this time the port 56 will communicate with a bleeder passage 76 which communicates with the passage 42 which at this time is connected with exhaust pressure through the channel 54, the port 38, and the passage 39, and accordingly the pressure space 65 will remain at discharge pressure owing to the fact that such fluid which may leak thereinto under pressure may pass out through the orifice member 73, the passage 72, the port 56, and the passage 76 into the passage 42 in which discharge pressure exists. In view of this, the pressure of fluid against the upper end face 74 will hold the valve member 53 in lowered position until passages or channels 77 formed at the upper end of the pilot rod 32 are carried in response to downward movement of the piston member 24 and the pilot rod 32 into such position that they will connect the space 58 with the port 62 and thereby deliver fluid under pressure through the passages 68 into the pressure chamber 65 at a much higher rate of flow than fluid can leak from the pressure chamber 65 through the orifice member 73; and owing to the fact that the area of the lower end face 67 of the valve member 53 is approximately twice that of the upper end face 74, the pressure of fluid thus introduced into the pressure chamber 65 will move the valve member 53 back into the raised position in which it is shown in Fig. 1, and the passages 58 and 42 will be again so connected that fluid under pressure will be conducted into the lower cylinder space 52, and the upper cylinder space 37 will be connected with the discharge passage 39, thereby producing an upward movement of the piston 24. The pumping cylinder 25 has a shell 44a and a liner 45a, both substantially identical in construction to the shell and liner 44 and 45. The upper end of the shell 44a has an extending tubular wall portion 78 which is in threaded engagement with the lower end of the connector body 48 and encloses between the connector body

48 and the upper end of the liner 45a a space for receiving the valve means 28 consisting of an annular valve seat body 80 which fits against the lower face of the connector body 48 in face-to-face relation, and a valve cage 81 disposed between the valve body 80 and the upper end of the liner 45a. The lower end of the shell 44a has an extending tubular wall 82 which has its lower end in threaded engagement with a lower connector body 83 having a valve cage 84 formed upon the upper end thereof within a space 85. Above the valve cage 84 is a valve seat body 85a which engages the lower end of a valve cage 86 and the upper end of the valve cage 84. A hollow rod 87 extends downwardly from the piston 26 through the members 86, 84, and 83 into a bull plug 88 which is threaded into the lower end of the connector body 83 and projects downwardly within the foot fitting 17. The connector body 48, Fig. 2, has discharge passages 90 connecting the space 32 outside the pump with chambers 91 in which discharge valve balls 92 are held in engagement with seats formed at the upper ends of passages 93 in the valve seat body 80, which passages 93 connect through passages 94 in the valve cage 81 with the upper pumping cylinder space 95 within the liner 45a of the pumping cylinder 25. Accordingly, when the piston 26 is moved upwardly, oil will be forced from the upper cylinder space 95 through the passages 94, 93, and 90 into the production or discharge column formed by the piping 11. When the piston 26 moves downwardly, the valve balls 92 drop into closed position relative to their cooperating seats, and oil from the well will be drawn into the upper pumping cylinder space 95 through passages 96 which are formed in the valve seat body 80 in downwardly facing relation and which communicate through ports 97 with oil inlet passage means consisting of an annular space 98 around the members 80 and 81, vertical passages 40a formed between the liner 45a and the shell 44a, an annular space 99 around the members 86 and 84 forming the lower valve structure 30 within the tubular wall 82, and passages 100 which extend through the lower connector body 83 into communication with the oil inlet space 101 within the foot fitting 17, which space 101 receives oil from the well through the pipe 14. The lower ends of the passages 96 are adapted to be closed by intake valve balls 102 which are urged upwardly by spring means 103. The oil which is drawn inwardly through the passages past the balls 102 is carried through an annular groove 104 in the upper end of the valve cage 81, which groove or channel 104 connects the passages 94 with the passages 96.

The lower valve seat body 85a has discharge passages 105 extending downwardly there-through which connect with the lower pumping cylinder space 106, the lower ends of which passages 105 are closed by discharge valve balls 107 which are disposed within the upper ends of openings 108 of the valve cage 84 and are urged upwardly by spring means 109. The upper ends of the openings 108 connect through an annular channel 111, formed in the upper end of the valve cage 84, with the upper ends of coaxial passages 112, the lower ends of which are connected through ports 113 with the space 22. Accordingly, downward movement of the piston 26 accomplishes a discharge of oil from the lower cylinder space into the discharge column formed by the piping 11. When the piston 26 moves upwardly, oil is drawn thereinto from the space

85 through an inlet passage 114 having cooperating check valve means 115 therein and which connects, by means of the annular channel 116, with the passages 105, the upper ends of which connect with the lower end of the lower cylinder space 106.

Very marked difficulties in the location and formation of fluid passages in pump structures of small diameter have very materially retarded the development of fluid operated deep well pumps. In order to produce the necessary cylinders, passages, and other cooperating parts, it is necessary to use thin wall members, many of which are subject to high stress due to the high fluid pressures encountered in the pumping of deep wells. If high efficiency is to be maintained under these high fluid pressures, very close fits must be maintained between the cooperating moving parts, and the parts must be so constructed that deformation thereof will not introduce frictional loads. In Fig. 6, which shows the motor or power cylinder and power piston of my deep well pump, I illustrate a very important advance of my invention over the prior art. The liner 45 comprises a relatively thin cylindrical wall of a metal having reasonable good wear resisting or frictional qualities. The liner 45, if the piston 26 is made from hardened steel, may be made from cast iron, a material which does not have a high modulus of elasticity; therefore, without my improved method of supporting such liner, fluid pressures acting on the exterior thereof would operate to reduce the diameter of the liner 45 to such an extent that the efficiency of the pump would be interfered with, and high fluid pressure within the liner would likewise result in an undesirable expansion thereof.

With respect to the construction of the power cylinder 23 and the pumping cylinder 25, my improvement consists in placing the liner, such as 45 or 45a, under an initial stress so as to contract or constrict the same, such initial stress being preferably as great as or greater than the compressive stress which may be exerted in the liner due to the presence of high pressure fluid around the liner, as, for instance, in the passages 40 and 40a. This initial stress is placed in the liner by making the external diameter of the liner greater than the internal diameter of the shell and then placing the shell upon the liner so that the shell acts to constrict the liner to a smaller diameter and accordingly places the liner under an initial stress. The placing of the shell upon the liner may be readily accomplished by subjecting the liner and the shell respectively to relatively low and high temperatures, placing the liner within the shell, and then permitting the temperatures of these members to equalize. For example, the shell may be heated to cause the same to expand sufficiently to slide over the liner, or the liner may be refrigerated so as to cause it to shrink to such size that it will slide into the shell. Also, the shell may be expanded by fluid pressure to such size that the liner will enter the axial opening thereof, and likewise the liner may be reduced in diameter by fluid pressure.

During the upward movement of the piston 24, the passages 40 and the lower space 52 may be subjected to a fluid pressure as high as 10,000 pounds per square inch, and at this time the fluid pressure outside the shell 44 would possibly be as high as 5,000 pounds per square inch, assuming that the pump is operating in a well at

a depth in excess of 10,000 feet and that there is this head of oil in the piping 11. Such pressures acting on the lower end of the liner 45 will cause the same to slightly expand, and in a pump constructed in accordance with the dimensions A, B, C, and D of Fig. 6, this expansion of the liner under the maximum pressures above noted is .0006 inch. At the same time, that is, with the power fluid being applied through the passages 40 to the lower end of the piston 24, the upper space 37 of the cylinder 23 will be open to discharge, or, in other words, will be connected with the static head of oil within the piping 11 outside the pump 15 and the pressure pipe 18. Accordingly, the pressure outside the liner within the passage 40, tending to constrict the liner, would be 10,000 pounds per square inch, and the fluid pressure within the upper part of the liner, tending to expand the same, would be approximately 5,000 pounds per square inch, leaving an inwardly acting differential of 5,000 pounds per square inch. In view of the fact that the liner has been placed under an initial compressive or constrictive stress, the differential of fluid pressure exerted in the upper parts of the passages 40 produces but little constriction of the upper portion of the liner 45, owing to the fact that this pressure differential is at the same time operating outwardly against the inner face of the shell 44 to expand the shell 44 so as to relieve the compressive action thereof on the upper portion of the liner 45 in somewhat the same manner as the fluid operates to contract the upper portion of the liner 45. In other words, the fluid pressure operating in the upper parts of the passages 40 operates to replace the compressive action of the shell 44 with the compressive action of the fluid. Accordingly, under the above extreme conditions of operation a pressure differential of 5,000 pounds between the passages and the space 37 produces a diametral contraction of the upper portion of the liner 45 of .00024 inch, which is less than the initial clearance between the piston 24 and the liner 45 which may vary between .0003 and .0008 inch. Therefore, the piston will not be gripped by the liner, or frictional losses will not be set up by the contraction of the liner.

The pump disclosed in this specification, made to operate in a 2½ inch tubing, has the diametral dimensions A, B, C, and D shown in Fig. 6, it being understood that these dimensions are for one of the pumps which has been made and used and that these dimensions may be materially varied without greatly changing the conditions which have been herein discussed. Even though the thin liner and shell walls are employed, my invention makes it possible to limit the diametral contraction and expansion of the liner to such small amounts that the efficiency of the pump from a practical standpoint will not be changed. For example, the piston 24 and the liner 45 are made with a difference in their diameters of .0003 inch to .0008 inch. In the operation of the pump under maximum pressure, that is, with a maximum differential pressure of 5,000 pounds on opposite sides of the liner 45, my invention limits the contraction of the liner to .00024 inch and expansion of the liner to .0006 inch, whereas without the initial stress of the liner 45 this same pressure differential will produce a contraction of .003 inch and expansion of .0015 inch respectively on the upward stroke and downward stroke of the plunger,

the result being that under these pressures during the upward stroke of the piston 24 it will be gripped in a manner to prevent or retard upward movement thereof by the contraction of the upper part of the liner, and on the downward stroke the leakage of fluid by the plunger will be excessive.

With the use of my invention, that is, with the liner under initial stress, the following conditions are found during the downward stroke of the piston 24. The upper space 37 within the liner 45 will be open to pressure of the power fluid, and the passages 40 and the lower space 52 will be open to discharge. Assuming that the pump is subjected to the maximum pressure conditions hereinabove employed for the purpose of illustration, there will be a pressure of 10,000 pounds per square inch in the space 37, 5,000 pounds per square inch in the passages 40, and 5,000 pounds per square inch against the outer surface of the shell 44, which would result in a diametral expansion of the liner of .0006 inch. At the same time there will be a pressure of 5,000 pounds per square inch in the space 52 below the piston 24, and the portion of the liner 45 extending below the piston will be diametrically contracted .00024 inch. It is found that where the invention is employed, there is at no time sufficient contraction of the liner 45 to interfere with the operation of the pump. Thus it is seen that the liner is closed in ahead of the piston and opened up behind it, and the piston must act as a drift in a hole which is now actually smaller than the piston diameter. On the upward stroke similar conditions exist, and the clearances change in much the same way but to a different degree.

In the pump cylinder the same differential pressure is encountered, but it is always acting in the same direction and tending to expand the liner ahead of the piston and contract it behind the piston.

As further disclosed in the foregoing application, the various passages, valves, etc., must be formed from separate parts, and such parts, if efficiency is to be maintained in the pump structure, must be secured together in fluid-tight relation. This is very difficult owing to the space limitations controlling the extreme dimensions of the cooperating parts and to the fact that a number of joints must be made tight by the same closure. In my invention I employ cooperating parts having end faces which are carefully ground or lapped for co-engagement and provide means for positively holding these parts together in end-to-end engagement with sufficient pressure to prevent leakage through the joints which are thus provided between the cooperating parts. It is an especial feature of the invention to employ the change in size of one metal part, due to temperature variation, to produce the force necessary to provide the above described seal between the end faces of the parts which are to be held together in end-to-end relation. For example, the valve means 28 and 30 at the upper and lower ends of the pumping cylinder 25 are relatively complex and could not be commercially constructed without embodying therein my new principle of pressing these parts together in end-to-end relation so that the ground end faces thereof will form a positive seal. As shown in Fig. 2, there is a valve seat body 80 which must rest in fluid-tight engagement with the lower end of the connector body 48, and below the valve seat body 75

80 is a valve cage 81 which must make fluid-tight engagement with the lower end of the valve seat body 80 and the upper end of the liner 45a. It is found that the screwing of the connector body 48 into the threads shown at the upper end of the tubular wall 78 will not produce sufficient axial pressure to assure a perfect sealing engagement between the ends of the cooperating parts 48, 80, 81, and 45a, and at the same time seal the end of the tube against the shoulder of the connector body 48. I have in my invention accordingly provided a metal wall, in this instance, the tubular extension wall 78, which is in isolated relation to the parts 80 and 81 across which it extends, and which wall 78 connects the extreme member 48 with the opposite extreme member 45a of the group of members 48, 80, 81, and 45a which are to be held together in positive fluid-tight end-to-end engagement, and I employ the change in size, namely, the change in axial dimension, of the wall 78 to produce the force necessary to cause the desired end-to-end engagement of the cooperating passage forming parts. This is accomplished by locally heating the wall 78 so that it is sufficiently expanded so that it may be screwed up against the shoulder of the connector body 48 without producing a contact of the inner cooperating parts. When the wall 78 cools, it results in a contraction and produces a tension in the wall 78 which draws the connector body 48 toward the liner 45a, thereby pressing the ends of the parts 48, 80, 81, and 45a together with great force and insuring a fluid-tight seal therebetween but without opening the joint between the wall 78 and the shoulder of the connector body 48.

This procedure also applies to the assembly of the parts 84 and 86 within the downwardly extending tubular wall 82 at the lower end of the cylinder 25. Also, in the practice of my invention it is possible to cool the included parts, such as the parts 80 and 81, to extremely low temperature before placing them in operative position within the wall 78, which at this time is the normal room temperature. The connector body 48 is then screwed tightly against the tubular wall 78, and when the contracted parts 80 and 81 expand, the necessary end-to-end sealing pressure is obtained.

As shown in Fig. 6, the lower end of the cylinder 23 has a downwardly extending tubular wall 47, the contraction of which may be employed to hold the wall 50 at the upper end of the connector body tightly against the lower end of the liner 45. The upper end of the cylinder 23, Fig. 1, is shown with an upwardly extending wall 117 which makes threaded engagement with the lower end of the valve fitting 33, and the contraction of which is capable of employment to hold the lower end 118 of the valve liner 29 in fluid-tight engagement with the upper end of the cylinder liner 45.

It should be pointed out that the shrinking of the outer tube on the liner and the assembly of the other cooperating parts are operations which are not performed at the same time, and that the tube is only locally heated in the assembly of the parts. Therefore, the assembly does not disturb the original shrink fit of the tube on the liner.

Although I have herein shown and described my invention in simple and practical form, it is recognized that certain parts or elements thereof are representative of other parts, elements, or

mechanisms which may be used in substantially the same manner to accomplish substantially the same results; therefore, it is to be understood that the invention is not to be limited to the details disclosed herein but is to be accorded the full scope of the following claims.

I claim as my invention:

1. A method of assembling a device including a cylinder head member and a cylinder member having a liner therein so that said cylinder head member and said liner are in end-to-end fluid-tight relation, including the steps of: locally heating one of said members so as to cause it to expand; joining said members together in end-to-end relation; and equalizing the temperatures of said members so as to cause said one of said members to contract to form an end-to-end fluid-tight joint between said cylinder head member and said liner.

2. A method of assembling a cylinder and a cylinder head in fluid-tight relationship and holding a plurality of axially abutted interior parts in fluid-tight relationship with each other and with said cylinder head, including the steps of: causing a sufficient temperature differential between said cylinder and said parts so as to permit said cylinder to be connected to said cylinder head in fluid-tight relation without exerting a compressive pressure on said parts; and equalizing the temperature to produce an axial compression between said parts and between said parts and said head to form a fluid-joint between said parts and between said parts and said head without breaking the fluid-tight joint between said cylinder and said cylinder head.

3. A method of assembling a cylinder and two cylinder heads, the cylinder having a liner therein adapted to be engaged by said heads, including the steps of: heating said cylinder so as to cause it to expand; connecting said heads to said cylinder so as to form fluid-tight joints between said heads and said cylinder; and reducing the temperature of said cylinder so as to cause it to contract to form fluid-tight joints between said heads and said liner without breaking said fluid-tight joints between said cylinder and said heads.

4. A method of assembling a cylinder and two cylinder heads, the cylinder having a liner therein adapted to be engaged by said heads, including the steps of: locally heating said cylinder so as to cause it to expand; connecting said heads to said cylinder so as to form fluid-tight joints between said heads and said cylinder; and reducing the temperature of said cylinder so as to cause it to contract to form fluid-tight joints between said heads and said liner.

5. A method of assembling a cylinder and a cylinder head, said cylinder having a liner therein adapted to be engaged by said head, including the steps of: threading said cylinder on said head; locally heating said cylinder so as to cause it to expand; threading said cylinder into fluid-tight engagement with said head; and reducing the temperature of said cylinder to cause it to contract so as to form a fluid-tight joint between said head and said liner without breaking the fluid-tight joint between said cylinder and said head.

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