Feb. 17, 1953 C. J. COBERLY 2,628,562

FLUID-OPERATED PUMP WITH TANDEM BOOSTER PUMPS

Filed Aug. 30, 1948 3 Sheets-Sheet 1

Fig. 1

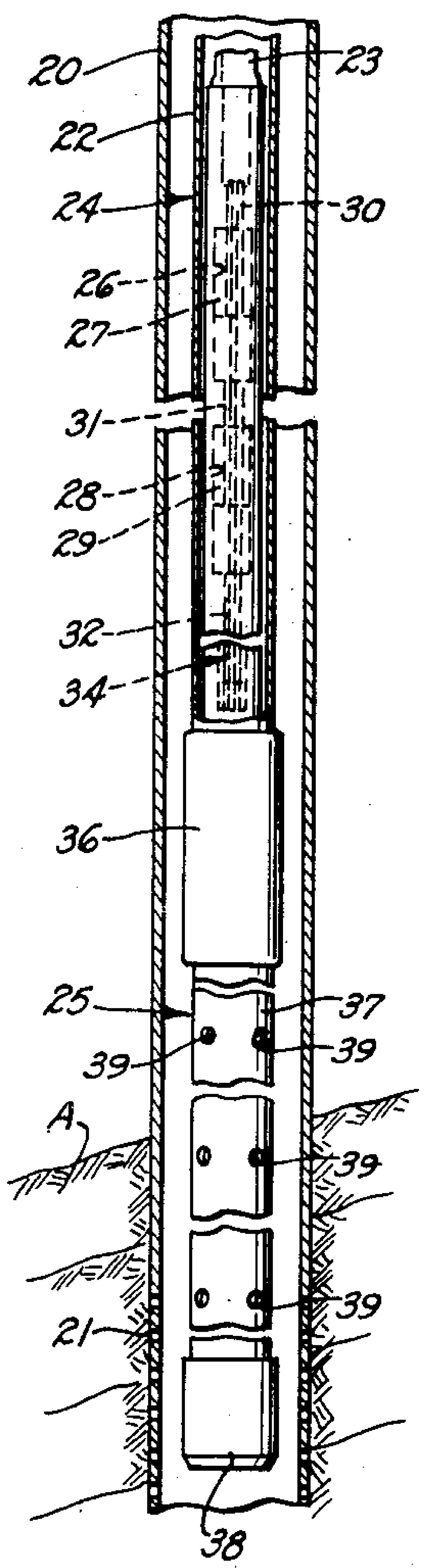


Fig. 2

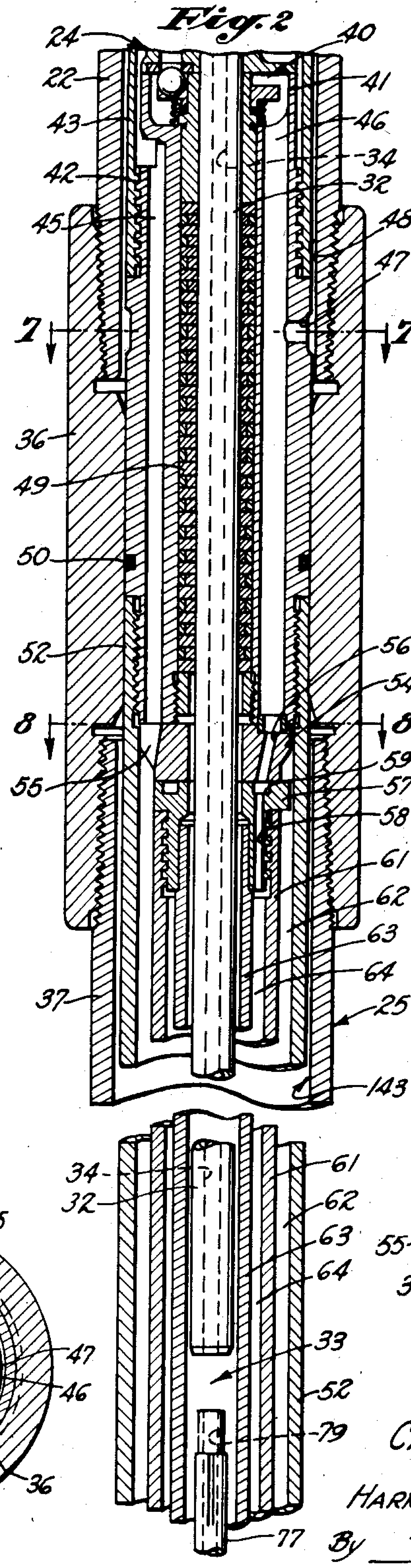


Fig. 3

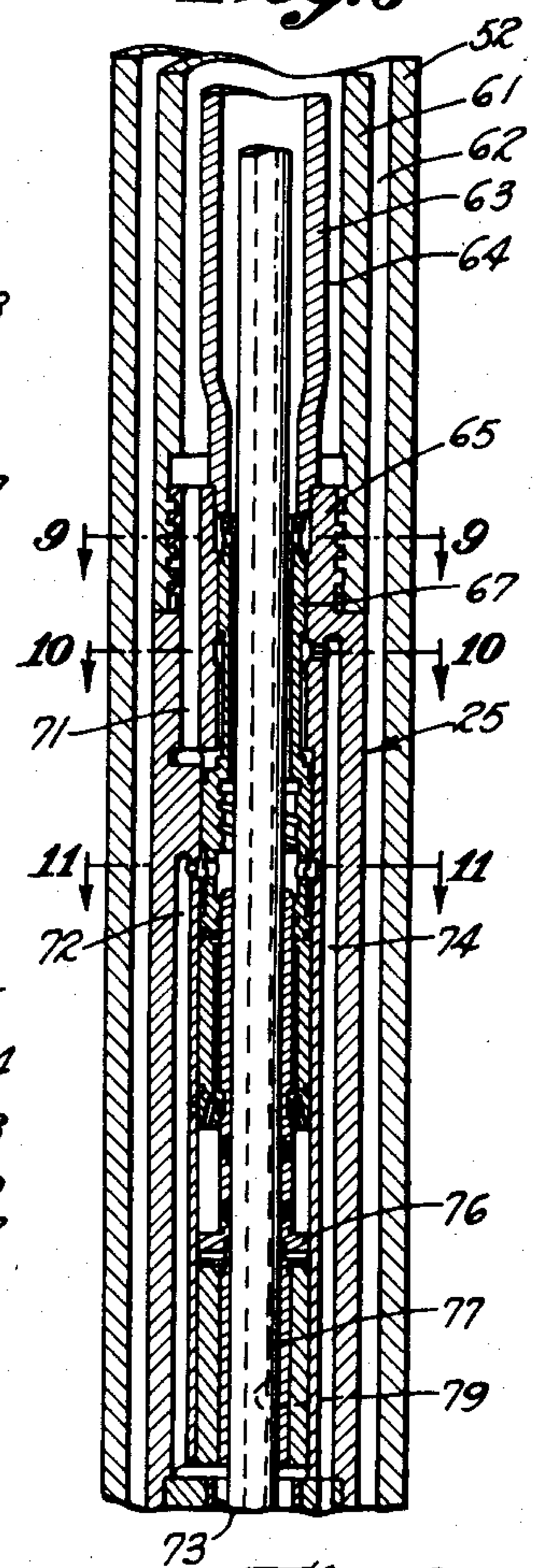


Fig. 7

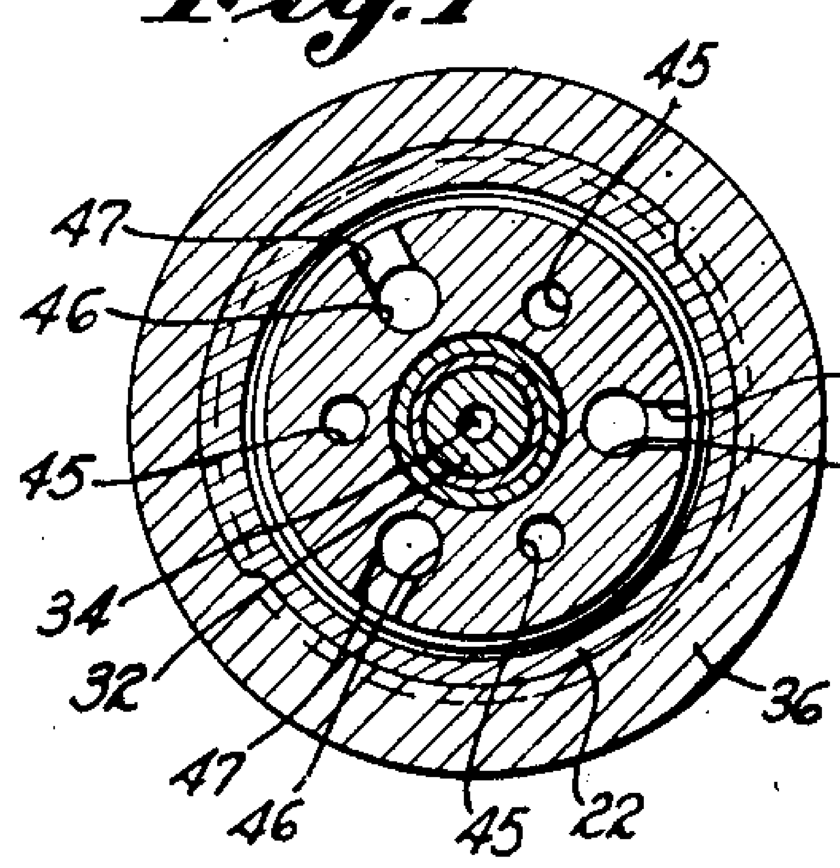
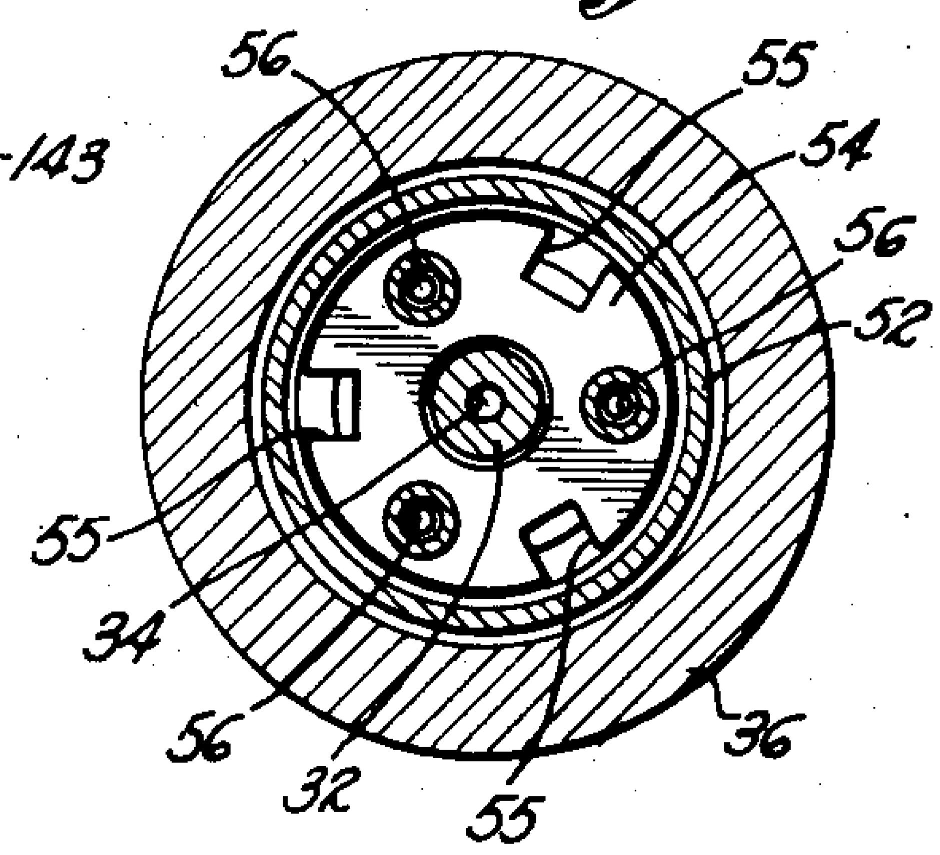


Fig. 8



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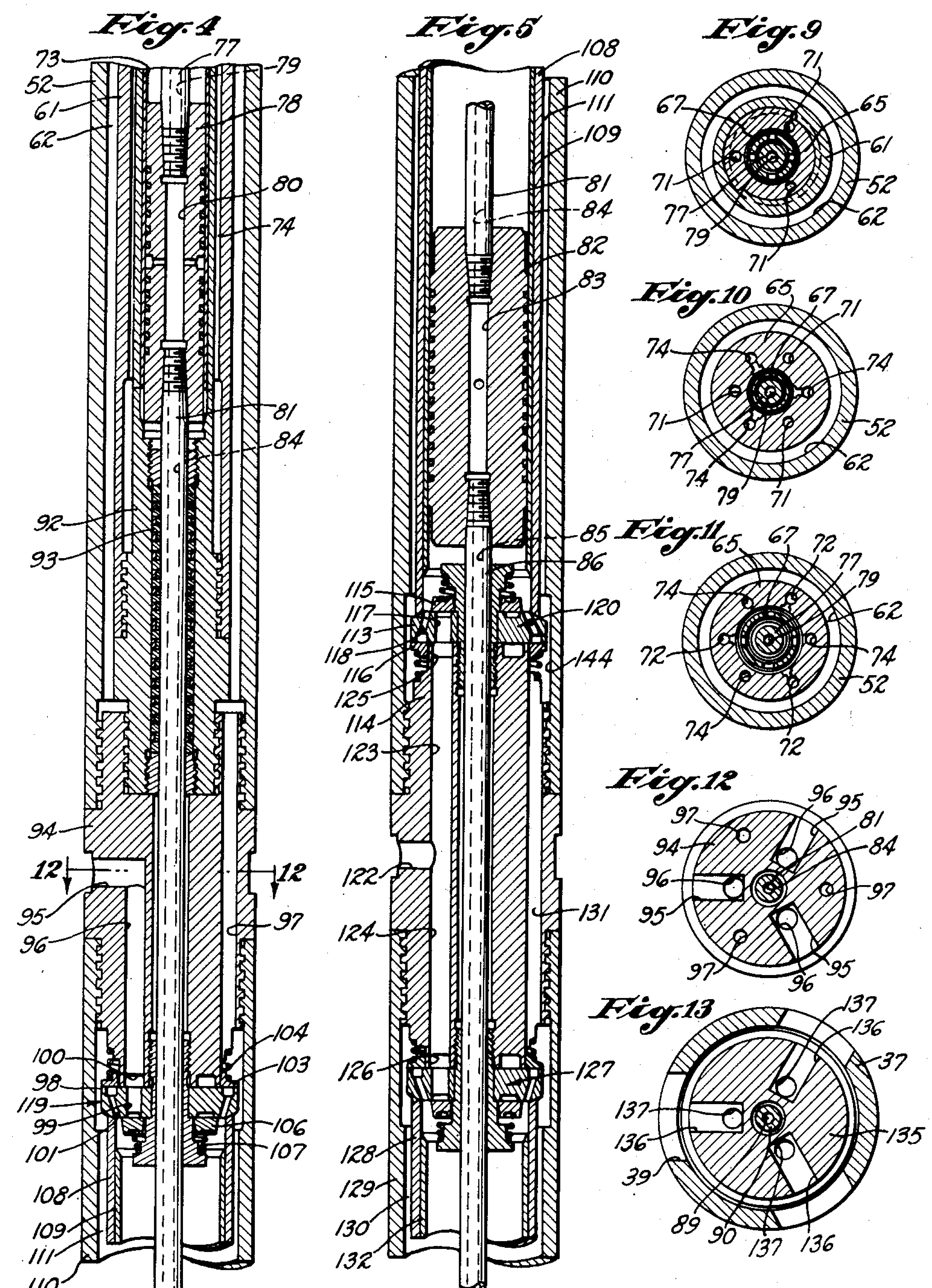
Feb. 17, 1953 C. J. COBERLY 2,628,562

FLUID-OPERATED PUMP WITH TANDEM BOOSTER PUMPS

Filed Aug. 30, 1948 3 Sheets-Sheet 2



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FLUID-OPERATED PUMP WITH TANDEM BOOSTER PUMPS

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Fig. 6

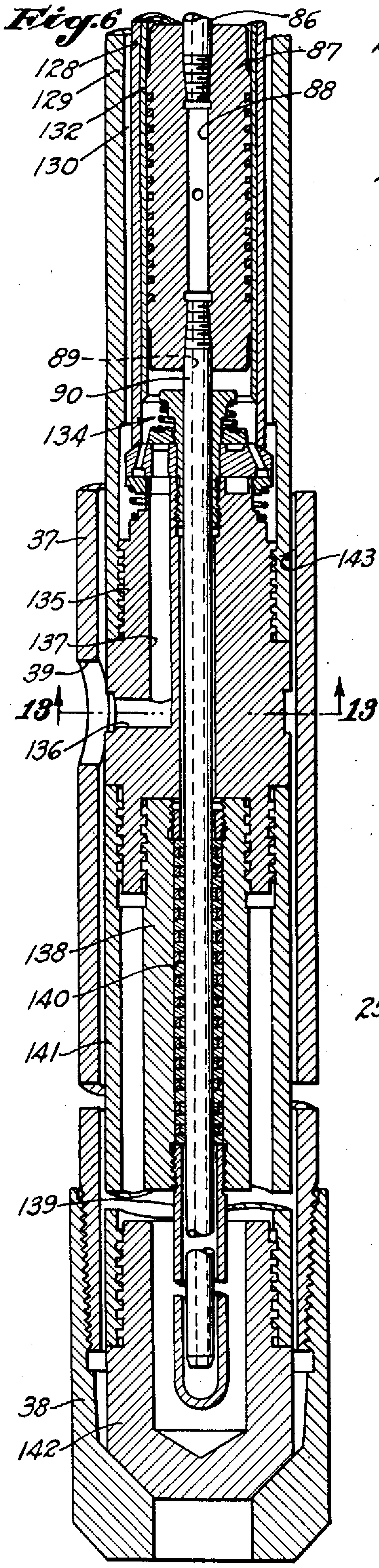


Fig. 14

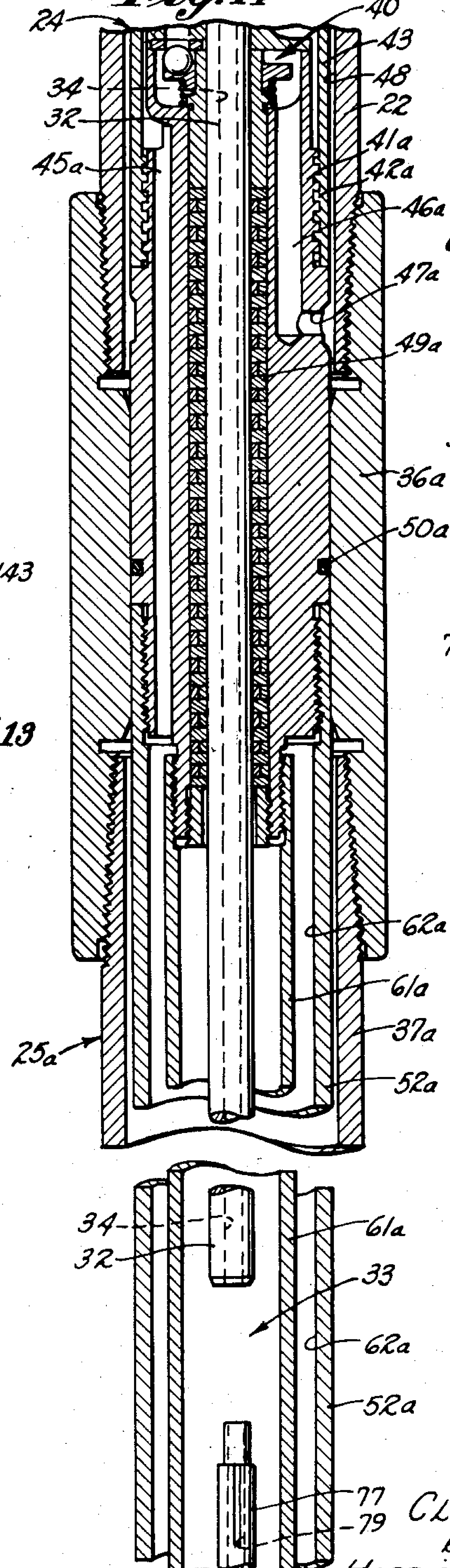
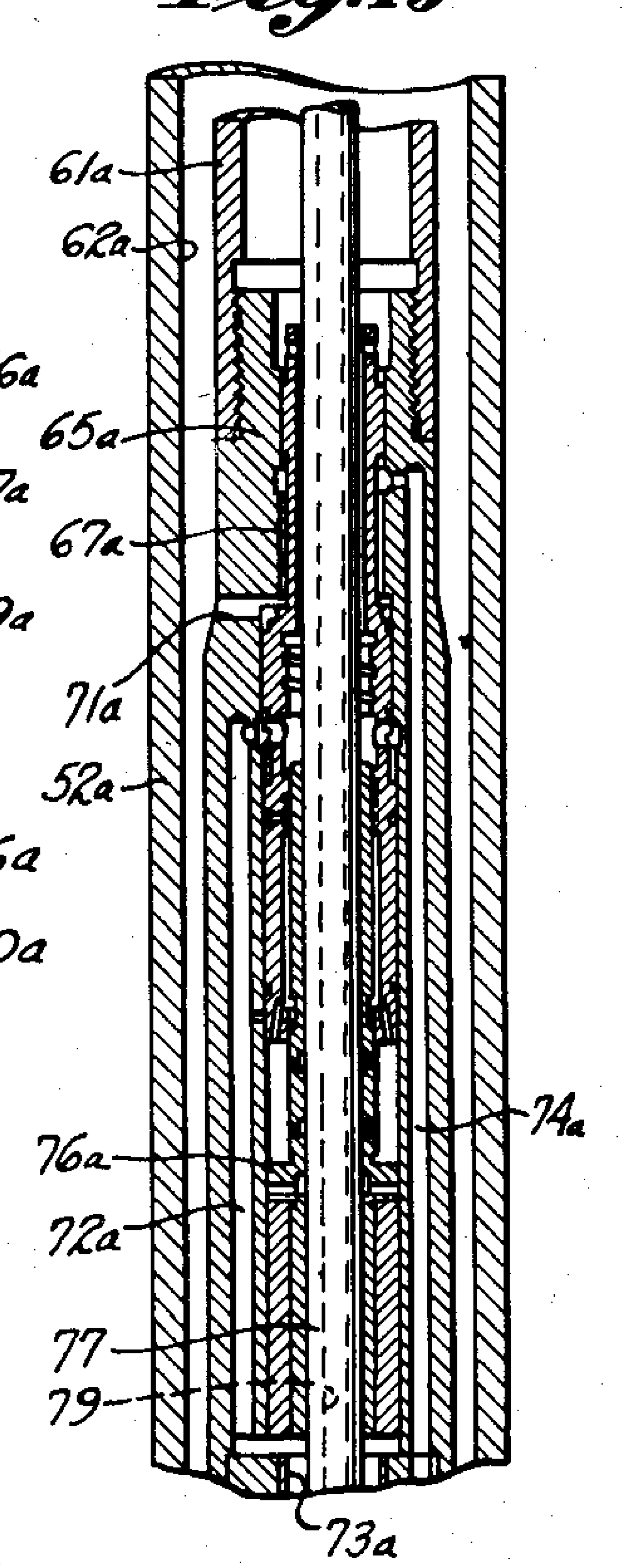


Fig. 15



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Patented Feb. 17, 1953 2,628,562

UNITED STATES PATENT OFFICE

2,628,562

FLUID-OPERATED PUMP WITH TANDEM BOOSTER PUMPS

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Application August 30, 1948, Serial No. 46,776

14 Claims. (Cl. 103—5)

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My invention relates in general to fluid-operated pumps for wells and, more particularly, to a fluid-operated pump having an auxiliary pumping means associated therewith for boosting the pressure of the well fluid delivered to the inlet of the main fluid-operated pump.

It is common practice in the oil industry to use fluid-operated pumps in pumping oil from wells, such a pump comprising, in general, a coupled motor and pump combination set in the well at the level from which oil is to be pumped. In such a pumping device, the motor comprises a motor piston which is actuated by admitting an operating fluid, such as clean crude oil, under relatively high pressure alternately into opposite ends of a cylinder in which the motor piston is disposed so as to reciprocate the piston. The reciprocatory motion of the motor piston is communicated to a pump piston in the pump end of the combination so that the pump piston pumps oil from the well. Ordinarily, fluid-operated pumps which are used commercially are of the double-acting type, i. e., they operate to pump oil from the well on both strokes of the pump piston.

The fluid being pumped from a well may contain, in addition to oil, various other fluids such as water and natural gas, the natural gas being present in solution or in suspension in the oil in varying quantities depending upon the conditions obtaining in the well. Also, if the well is being pumped beyond its capacity, air may be present in the fluid being pumped. Since such fluid-operated pumps are normally of the displacement type, considerable difficulty has been experienced with gas or air in the pump cylinder. If the well oil is saturated or super-saturated with natural gas at the prevailing pressure at the depth at which the pump is set, a large portion of the gas may be released during the suction stroke of the pump piston to collect as a pocket in the pump cylinder. Also, of course, in many wells the well fluid is merely a froth composed largely of gas with a relatively small volume of oil. In either case, or if air is drawn into the pump cylinder, a pocket of gas or air in the pump cylinder results. When such pockets form in the pump cylinder, the pumping load is materially reduced until such time as the pump piston compresses the gas or air in the pocket and strikes solid well fluid in the cylinder.

Such fluid-operated pumps are ordinarily operated at relatively great depths and, consequently, a large volume of operating fluid under high pressure is confined in the supply tubing between the pump in the well and the apparatus

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on the surface which delivers the operating fluid to the pump. Due to the compressibility of this large volume of operating fluid, and due to the expansion of the supply tubing under the relatively high pressure at which the operating fluid is maintained, a large amount of energy is stored in the system under normal operating conditions. If, due to the presence of gas or air in the pump cylinder, the load on the pump piston decreases, a sudden increase in the rate of flow of operating fluid to the pump occurs, thereby accelerating the motor and pump pistons. The speed attained may be excessive and the pump may race for a portion of a stroke, or for a number of strokes, which is normally detrimental to various components of the pump. Various expedients for preventing damage to the pump mechanism under such conditions have been attempted. For example, flow regulators disposed in the supply line for the operating fluid have been employed to maintain the rate of delivery of operating fluid to the motor section of the pump below a value which might be harmful to the pumping equipment. While such flow governors are practical under most conditions of operation, they have some disadvantages in that they increase the cost of the pumping equipment and render the equipment rather complicated.

In view of the foregoing considerations, it is a primary object of the present invention to provide, in combination with a conventional fluid-operated pump, an auxiliary or booster pump which is adapted to draw well fluid from the well and to deliver it to the inlet of the fluid-operated pump at an increased pressure such that the major portion of the gas or air in the well fluid will not flash out to form a pocket in the pump cylinder of the fluid-operated pump. I accomplish this by providing a booster pump which will maintain the pressure of the well fluid passing into the pump cylinder of the fluid-operated pump at a value equal to or above the prevailing pressure in the well at the inlet of the fluid-operated pump.

A further object of the invention is to provide a booster pump which will compress any free gas or air entrained in the well fluid to a substantial extent before it is delivered to the inlet of the fluid-operated pump.

It will be apparent that the efficiency of a conventional fluid-operated pump is inversely proportional to the volume of free gas or air in the pump cylinder and by the provision of a booster pump in combination with the fluid-operated pump, the efficiency of the latter is increased to a substantial extent, which is an important feature of the invention. Thus, if in a given installation 30% of the pump cylinder of the fluid-operated pump is occupied by free gas or air at atmospheric pressure, the efficiency of the pump, i. e., the percentage of the volume of the pump cylinder occupied by solid well fluid, will be only 70%. With the present invention, if the particular booster pump utilized is adapted to increase the pressure of the well fluid delivered to the inlet of the fluid-operated pump to 300 lbs. per square inch, for example, the free gas or air which otherwise would occupy 30% of the volume of the pump cylinder will be compressed to occupy only approximately 1.4% of the volume of the pump cylinder, thereby increasing the efficiency of the fluid-operated pump to approximately 98.6% under such conditions.

Another object of the present invention is to provide such a booster pump combination in which the booster pump is also fluid-operated. While it is contemplated that the booster pump may be operated by an independent source of fluid under high pressure, it is particularly advantageous to operate the booster pump from the same source of operating fluid as the main fluid-operated pump and, accordingly this is still another object of the invention.

A further object of the invention is to provide in such a combination a booster pump of the reciprocating type in which the operating fluid under pressure is delivered alternately to opposite ends of a motor cylinder incorporated in the booster pump to reciprocate one or more pump pistons incorporated therein.

Another object is to provide a combination of the foregoing character wherein the booster pump includes at least two pump pistons connected in tandem with the motor piston of the booster pump.

A further object is to provide a booster pump having two or more pump pistons in tandem and having inlet and discharge means common to the cylinders in which the pump pistons of the booster pump operate.

A further object is to provide a booster pump which is adapted to deliver a relatively large volume of well fluid to the main fluid-operated pump at a relatively low pressure.

Still another object is to provide a combination wherein the booster pump is connected to the lower end of the main fluid-operated pump and wherein operating fluid for the booster pump is delivered thereto through the main fluid-operated pump, the operating fluid for the main and booster pumps being derived from the same source of supply.

The foregoing objects and advantages of the invention, together with various other objects and advantages thereof which will become evident, may be attained through the utilization of the exemplary embodiments which are illustrated in the accompanying drawings and which are described in detail hereinafter. Referring to the drawings:

Fig. 1 is a utility view on a reduced scale showing a pumping installation which embodies the invention as installed in a well;

Fig. 2 is a longitudinal sectional view of the upper end of a preferred booster pump of the invention;

Figs. 3, 4, 5 and 6 are downward continuations of Figs. 2, 3, 4 and 5, respectively;

Figs. 7 and 8 are transverse sectional views

taken along the broken lines 7—7 and 8—8, respectively, of Fig. 2;

Figs. 9, 10 and 11 are transverse sectional views taken along the broken lines 9—9, 10—10 and 11—11, respectively, of Fig. 3;

Fig. 12 is a transverse sectional view taken along the broken line 12—12 of Fig. 4;

Fig. 13 is a transverse sectional view taken along the broken line 13—13 of Fig. 6;

Fig. 14 is a longitudinal sectional view similar to Fig. 2 but showing the upper end of an alternative booster pump of the invention; and

Fig. 15 is a downward continuation of Fig. 14.

Referring particularly to Fig. 1 of the drawings, I show a well casing **20** having perforations **21**, the well casing being set in an oil well so that the perforations are in registry with an oil producing sand A. Extending downwardly into the well casing **20** is a production tubing **22** which is adapted to convey oil to the surface of the ground, and extending downwardly into the production tubing is a power tubing **23** having a main or primary fluid-operated pump **24** connected to the lower end thereof. The fluid-operated pump **24** may be of any conventional type, such as that shown in my Patent No. 2,081,220, granted May 25, 1937, which is adapted to pump well fluid from the casing **20** upwardly through the production tubing **22** to the surface of the ground. Connected to the lower end of the primary fluid-operated pump **24** is an auxiliary fluid-operated pump **25**.

As diagrammatically shown in dotted lines in Fig. 1, the primary fluid-operated pump **24** includes a motor cylinder **26** having a motor piston **27** therein and includes a pump cylinder **28** having a pump piston **29** therein. Connected to the upper end of the motor piston **27** is an upper tubular rod **30** which extends upwardly into communication at all times with the interior of the power tubing **23**. Connecting the motor piston **27** and the pump piston **29** is an intermediate tubular rod **31**, and connected to the lower end of the pump piston is a lower tubular rod **32** which extends downwardly into a balance chamber **33**. Longitudinal passage means **34** extending through the upper rod **30**, the motor piston **27**, the intermediate rod **31**, the pump piston **29**, and the lower rod **32** permits operating fluid under relatively high pressure, such as clean crude oil, to flow from the power tubing **23** downwardly into the balance chamber **33**.

As shown in Fig. 2, the lower end of the production tubing **22** is threaded into a collar **36**, the latter having a depending tubular member **37** threaded into the lower end thereof. As shown in Fig. 6, threaded onto the lower end of the member **37** is a cup-shaped closure element **38**. As shown in Fig. 6, the tubular member **37** is provided with a plurality of main intake ports **39** arranged in upper, intermediate and lower groups, the ports **39** communicating with the interior of the well casing **20** adjacent the perforations **21**.

As shown in Fig. 2, the lower end of the fluid-operated pump **24** is provided with a discharge valve assembly **40** disposed in an end plug **41** which is threaded at **42** to the lower end of a pump barrel **43** of the primary fluid-operated pump **24**. The end plug **41** is provided with a plurality of circumferentially spaced, longitudinal inlet ports **45** and a plurality of circumferentially spaced, longitudinal discharge ports **46**, the discharge ports communicating through radial ports **47** with an annular space **48** between the pump barrel 43 and the inner wall of the production tubing 22. The lower tubular rod 32 extends downwardly through the end plug 41, there being suitable packing 49 therebetween. The end plug 41 makes a sliding fit with the inner wall of the collar 36, a fluid seal therebetween being provided by annular packing 50.

Threaded onto the lower end of the end plug 41 is a downwardly extending tubular member 52 which forms the outer barrel of the auxiliary fluid-operated pump 25. As shown in Fig. 2, the lower end of the end plug 41 is engaged by a spacer ring 54 having a plurality of notches 55 in the periphery thereof which register with the inlet ports 45, respectively. The spacer ring 54 also has provided therein a plurality of ports 56 which register, respectively, with the lower ends of the discharge ports 46. In engagement with the lower end of the spacer ring 54 is a ring element 57 having provided therein a plurality of longitudinal passages 58 which are circumferentially spaced from each other and which register at their upper ends with an annular groove 59 which in turn registers with the ports 56.

Threaded on the ring element 57 is a downwardly-extending central tubular member 61 which is spaced from the tubular member 52 so as to provide therebetween an annular space 62, the upper end of which communicates with the notches 55 of the spacer ring 54. Pressed into the lower end of the ring element 57, and seated thereon, is a balance tube 63 which is spaced from the central tubular member 61 so as to provide an annular space 64 therebetween. As will be noted, the lower end of the lower tubular rod 32 extends downwardly into the balance tube 63, the lower end of the balance tube forming the balance chamber 33.

As shown in Fig. 3, the lower end of the central tubular member 61 is threaded onto a valve body 65 of the auxiliary fluid-operated pump 25, the lower end of the balance tube 63 seating on the upper end of the valve body. The valve body 65, and the valve mechanism therein, is similar to that shown in my Patent No. 2,311,157, issued February 16, 1943, to which reference is hereby made for a detailed description thereof. As a matter of general explanation, however, within the valve body 65 is a tubular, differential-area-type valve member 67 which alternately admits operating fluid into the upper and lower ends of a motor cylinder in the booster pump 25 to reciprocate a motor piston therein as will be described in more detail hereinafter. The valve member 67 is similar to the valve member 60 of the pump disclosed in my aforesaid Patent No. 2,311,157 and operates in a similar manner so that a further description thereof herein is unnecessary.

The upper end of the valve body 65 is provided with longitudinal exhaust passages 71, the upper ends of which communicate with the annular space 64. Formed in the valve body are motor inlet and discharge passages 72 which communicate at their lower ends with the upper end of a motor cylinder 73. Also formed in the valve body 65 are motor inlet and discharge passages 74 which communicate with the lower end of the motor cylinder 73. Supported in the valve body 65 is a sleeve element 76 which journals an upper rod member 77 the lower end of which, as shown in Fig. 4, is threaded into a motor piston 78 in the cylinder 73. As shown in Fig. 2, the upper end of the upper rod member 77 extends into the balance chamber 33, this upper rod member controlling the operation of the valve member 67 as described in my aforesaid Patent No. 2,311,157. The upper rod member 77 is provided with a longitudinal passage 79 therethrough which communicates with a central bore 80 extending through the motor piston 78. Threaded into the lower end of the motor piston 78 is an intermediate tubular rod 81 having a longitudinal passage 84 therethrough, the lower end of the intermediate rod, as shown in Fig. 5, being threaded into an upper pump piston 82. The upper pump piston 82 has an axial bore 83 therethrough which communicates at its upper end with the longitudinal passage 84 formed in the intermediate tubular rod and at its lower end with a longitudinal passage 85 formed in another intermediate tubular rod 86, the latter being threaded into the lower end of the upper pump piston 82 and, as shown in Fig. 6, being threaded into the upper end of a lower pump piston 87. The lower pump piston 87 has a central bore 88 therethrough which communicates at its lower end with the upper end of a longitudinal passage 89 formed in a lower tubular rod 90 which is threaded into the lower end of the piston 87 and which extends downwardly therefrom.

As shown in Fig. 4, the lower end of the tubular member 61 is closed by a tubular plug 92 which is threaded thereinto, packing 93 being provided between the plug 92 and the intermediate tubular rod 81. Threadedly connected to the lower ends of the tubular member 52 and the tubular plug 92 is a head member 94 having a plurality of radial intake ports 95 which respectively communicate with longitudinal intake passages 96 extending downwardly to the lower end of the head member. The ports 95 are located opposite the upper group of ports 39 in the tubular member 37. Also formed in the head member 94 is a plurality of longitudinal passages 97, the upper end of which communicates with the annular space 62.

Engaging the lower end of the head member 94 is a valve seat member 98 having a plurality of intake ports 99, only one of which is visible in Fig. 4, communicating with an annular groove 100 formed in the lower end of the head member 94, and having a plurality of discharge ports 101. The annular groove 100 also communicates with the lower ends of the passages 96. Carried on the upper face of the valve seat member 98 is a discharge valve ring 103 which is normally held in its closed position by a compression spring 104. As will be understood, the valve ring 103 normally closes the discharge ports 101. Engaging the lower face of the valve seat member 98 is an inlet valve ring 106, a compression spring 107 resiliently retaining this valve ring in its closed position so as to close the intake ports 99.

Also engaging the lower end of the valve seat member 98 is an upper pump cylinder 108 having a liner 109 therein, the pump cylinder being spaced from a tubular pump barrel 110 so as to provide an annular space 111 therebetween. As shown in Fig. 5, the upper pump piston 82 is slidably disposed in the liner 109 of the upper pump cylinder 108. The lower end of the pump cylinder 108 rests on a lower valve seat member 113 which is identical with the valve seat member 98 but inverted in position, the valve seat member 113 resting on the upper end of a heat member 114 which is threaded into the lower end of the pump barrel 110. As will be apparent, the valve seat member 98, the upper pump cylinder 108 and the lower valve seat member 113 are clamped between the head members 94 and 114 by tightening the threaded connections between the upper pump barrel 110 and the head members. The lower valve seat member 113 is engaged by an inlet valve ring 115 and a discharge valve ring 116 and is provided with intake ports 117 and discharge ports 118, which form a lower inlet and discharge valve means 120 for the upper pump cylinder 108. As will be understood, the valve seat member 98 and its valve rings 103 and 106 form an upper inlet and discharge valve means 119 for the upper pump cylinder 108.

The head member 114 is provided with a plurality of radial intake ports 122 which communicate with groups of upper and lower intake passages 123 and 124, the latter in turn communicating with annular grooves 125 and 126, respectively. The intake ports 122 are located opposite the intermediate groups of intake ports 39 in the tubular member 37. Disposed below the head member 114 is an inlet and discharge valve means 127 which is identical with the inlet and discharge valve means 119, the valve means 127 being disposed at the upper end of a pump cylinder 128 which is disposed within and spaced from a lower pump barrel 129 so as to provide an annular space 130 therebetween which communicates at its upper end with a longitudinal passage 131 formed in the head member 114. The lower pump cylinder 128 is provided with a liner 132 in which the lower pump piston 87 is slidably disposed. At the lower end of the lower pump cylinder 128 is provided an inlet and discharge valve means 134 which is in all respects identical with the inlet and discharge valve means 120. The lower end of the lower pump barrel 129 is threaded onto a lower head member 135 which is provided with a plurality of radial intake ports 136 communicating with longitudinal intake passages 137. The intake ports 136 are located opposite the lower group of intake ports 39 in the tubular member 37. Threaded into the lower end of the lower head member 135 is an inner tubular member 138, the lower end of which is closed by a threaded cap 139, and through which extends the lower tubular rod 90, there being suitable packing 140 disposed around the rod. Also threaded onto the lower end of the head member 135 is an outer tubular member 141, the lower end of the latter being closed by a cap 142 which is tapered to seat in a tapered seat in the cup-shaped closure element 38 of the tubular member 37.

It will be noted that a continuous annular passage 143 extending from the upper end of the tubular member 37 to the lower end thereof is provided between this member and the tubular member 52, the head member 94, the upper pump barrel 110, the head member 114, the lower pump barrel 129, the head member 135, the tubular member 141 and the cap 142. The annular passage 143 thus interconnects the main intake ports 39, the intake ports 95 in the head member 94, the intake ports 122 in the head member 114, and the intake ports 136 in the head member 135 to form a common inlet means for the pump cylinders 108 and 128. As previously indicated, the intake ports 95 communicate with the upper end of the upper pump cylinder 108 through the inlet and discharge valve means 119, the intake ports 122 respectively communicate with the lower end of the upper pump cylinder 108 and the upper end of the lower pump cylinder 128 through the inlet and discharge valve means 120 and 127, and the intake ports 136 communicate with the lower end of the lower pump cylinder 128 through the inlet and discharge valve means 134.

In operation, an operating fluid, such as clean crude oil, is conveyed under high pressure downwardly through the power tubing 23 from a suitable source (not shown) on the surface of the ground. A portion of such operating fluid flows downwardly through the longitudinal passage means 34 into the balance chamber 33, as is conventional in such a fluid-operated pump as shown in my aforesaid patent No. 2,311,157. The operating fluid then flows downwardly through the balance tube 63 and into the auxiliary fluid-operated pump 25. Subsequently, with the valve member 67 in the position shown in Fig. 3, the operating fluid flows downwardly around the upper rod member 77 and outwardly through suitable radial ports in the valve member 67 into the motor inlet and discharge passages 72, through which it flows downwardly into the upper end of the motor cylinder 73, exerting a downward force on the motor positon 78 causing it to move downward, the motor piston being shown approaching the lower end of its stroke in Fig. 4. Downward movement of the motor piston 78 of course results in downward movement of the upper and lower pump pistons 82 and 87.

When the upper pump piston 82 moves downwardly it creates a suction thereabove to draw well fluid from the well casing 20 inwardly through the ports 39 in the tubular member 37 and into the upper end of the upper pump cylinder 108 through the radial intake ports 95 and the longitudinal intake passages 96, the inlet valve ring 106 of the inlet and discharge valve means 119 moving off its seat against the action of the compression spring 107 to permit the well fluid to be drawn into the upper end of the upper pump cylinder. Similarly, well fluid is drawn into the upper end of the lower pump cylinder 128 through the ports 39 in the tubular member 37, the radial intake ports 122 and the longitudinal intake passages 124, the inlet valve ring of the inlet and discharge valve means 127 unseating to permit this to occur.

As the motor piston 78 and the pump pistons 82 and 87 of the booster pump 25 move downwardly in the foregoing manner, spent operating fluid previously admitted into the lower end of the motor cylinder 73 is discharged therefrom through the longitudinal passages 74. Such spent operating fluid flows from the passages 74 through suitable passages formed in the valve body 65 and the valve member 67 into the motor exhaust passages 71. From the latter, the spent operating fluid flows through the annular space 64, the passages 58, the discharge ports 56 and 46 and through the radial discharge ports 47 into the annular space 48 between the production tubing 22 and the barrel 43 of the main fluid-operated pump 24. The spent operating fluid subsequently mixes with the production fluid pumped by the main fluid-operated pump 24.

As the spent operating fluid is discharged from the lower end of the motor cylinder 73 of the booster pump 25 into the production tubing 22 in the foregoing manner during downward movement of the motor piston 78 and the pump pistons 82 and 87, well fluid previously drawn into the lower ends of the pump cylinders 108 and 128 is discharged therefrom. The well fluid in the lower end of the pump cylinder 128 is discharged therefrom into the annular space 130 through the inlet and discharge valve means 134, the discharge valve ring of the inlet and discharge valve means 134 unseating to permit this to occur. The well fluid discharged from the lower end of the pump cylinder 128 flows upwardly through the annular space 130 into the longitudinal passages 131 and thence into an annular space 144 (Fig. 5) adjacent the inlet and discharge valve means 120 for the lower end of the upper pump cylinder 108. The well fluid in the lower end of the upper pump cylinder is discharged into the annular space 144 through the inlet and discharge valve means 120, the discharge valve ring 116 of the latter unseating automatically to permit such discharge from the lower end of the upper pump cylinder. Thus, the well fluid discharged from the lower ends of the upper and lower pump cylinders 108 and 128 finds its way into the annular space 144. From the latter, the well fluid discharged from the lower ends of the upper and lower pump cylinders 108 and 128 flows upwardly through the annular space 111, the longitudinal passages 97, and annular space 62, the notches 55 in the spacer ring 54, and through the inlet ports 45 into the main fluid-operated pump 24.

As the motor piston 78 and the pump pistons 82 and 87 reach the lower ends of their respective strokes, the valve member 67 moves to a position such that it admits operating fluid to the lower end of the motor cylinder 73 so that the operating fluid exerts an upward force on the motor piston 78, thereby causing the motor piston and the pump pistons 82 and 87 to move upwardly. As the motor piston 78 and the pump pistons 82 and 87 move upwardly, the spent operating fluid in the upper end of the motor cylinder 73 and the well fluid previously drawn into the upper ends of the pump cylinders 108 and 128 are discharged therefrom in a manner similar to that hereinbefore described, the spent operating fluid from the upper end of the motor cylinder eventually being discharged into the annular space 48 between the production tubing 22 and the barrel 43 of the main fluid-operated pump 24, and the well fluid from the upper ends of the pump cylinders eventually being discharged into the inlet ports of the main fluid-operated pump.

Thus, the auxiliary or booster pump 25 delivers well fluid to the inlet of the main fluid-operated pump 24 at an elevated pressure to minimize the formation of gas pockets in the pump cylinder 28 of the main fluid-operated pump, whereby to increase the efficiency of the main fluid-operated pump and to minimize the possibility of damage to the components thereof which may result from the formation of gas pockets in the pump cylinder 28 as previously discussed. The booster pump 25 preferably delivers a relatively large volume of well fluid to the main fluid-operated pump 24 at a relatively low pressure, the total effective cross-sectional area of the booster pump piston 82 and 87 being substantially larger than the effective cross-sectional area of the booster motor piston 78 to accomplish this. In practice, this ratio of pump piston area to engine piston area may be 5:1 to 8:1, for example. Thus, the major portion of the work necessary to pump the well fluid to the surface is performed by the main fluid-operated pump 24, the function of the booster pump 25 being to deliver the well fluid to the main pump at a pressure sufficient only to prevent excessive formation of gas pockets in the pump cylinder 28 of the main pump.

It will be noted that, as best shown in Fig. 2 of the drawings, the production fluid discharged by the main fluid-operated pump 24 flows past the discharge valve assembly 40 into the discharge ports 46. From the latter, the production fluid pumped by the main pump flows through the radial discharge ports 47 into the annular space 48 between the production tubing 22 and the barrel 43 of the main fluid-operated pump, the production fluid subsequently flowing upwardly through the production tubing to the surface. As will be apparent, the spent operating fluid discharged from the motor cylinder 73 of the booster pump 25 mixes with the production fluid discharged by the main pump 24 in the longitudinal discharge ports 46 and the radial discharge ports 47 and the resulting mixture subsequently flows upwardly through the production tubing 22. Thus, it will be apparent that in the embodiment thus far described, the spent operating fluid from the booster motor cylinder 73 is mixed with the fluid being pumped after the latter has been discharged by the main fluid-operated pump 24.

In the embodiment illustrated in Figs. 14 and 15 of the drawings, on the other hand, the spent operating fluid from the motor cylinder of the booster pump is mixed with the fluid delivered to the inlet of the main pump so that both the spent operating fluid from the motor cylinder of the booster pump and the well fluid delivered to the main pump by the booster pump are pumped by the main pump. The embodiment illustrated in Figs. 14 and 15 of the drawings will now be considered in detail.

The embodiment now under considerating differs from that described previously principally in the rearrangement of certain of the passages in the upper end of the booster pump and in the elimination of certain of the parts in the upper end of the booster pump. For convenience, the components of the embodiment of Figs. 14 and 15 will be identified by adding the suffix "*a*" to the numerals used to identify corresponding components of the embodiment of Figs. 1 to 13. Thus, as shown in Fig. 14 of the drawings, the lower end of the production tubing 22 is threaded into a collar 36*a* of a booster pump 25*a*, this collar having a depending tubular member 37*a* threaded into the lower end thereof. The discharge valve assembly 40 at the lower end of the fluid-operated pump 24 is disposed in an end plug 41*a* which is threaded at 42*a* to the lower end of the pump barrel 43 of the primary fluid-operated pump 24. The end plug 41*a* is provided with a plurality of circumferentially spaced, longitudinal inlet ports 45*a* and a plurality of circumferentially spaced, longitudinal discharge ports 46*a*, the latter communicating through radial discharge ports 47*a* with the annular space 48 between the pump barrel 43 and the production tubing 22. In this embodiment, the longitudinal discharge ports 46*a* terminate at the ports 47*a* and do not extend therebelow. The lower tubular rod 32 of the main fluid-operated pump 24 extends downwardly through the end plug 41*a*, suitable packings 49*a* being provided between the rod 32 and the end plug 41*a*. The end plug 41*a* makes a sliding fit with the inner wall of the collar 36*a*, a fluid seal therebetween being provided by an annular sealing ring **50***a*.

Threaded onto the lower end of the end plug **41***a* is a downwardly extending tubular member **52***a* which forms the outer barrel of the auxiliary fluid-operated pump **25***a*. Also threaded onto the lower end of the end plug **41***a* is a downwardly extending tubular member **61***a* which corresponds to the tubular member **61** of the embodiment hereinbefore described. It will be noted that the spacer ring **54** and the balance tube **63** of the previously described embodiment are eliminated in the embodiment now under consideration, the tubular member **61***a* serving as a balance tube in the present instance. Provided between the tubular member **61***a* and the tubular member **52***a* is an annular space **62***a* which corresponds to the annular space **62** in the previous embodiment. It will be noted that the annular space **62***a* communicates with the longitudinal inlet ports **45***a* of the main pump **24**, as in the previous embodiment.

As shown in Fig. 15, a valve body **65***a* is threaded into the lower end of the central tubular member **61***a* and is provided with a tubular, differential-area-type valve member **67***a* which corresponds to the valve member **67**. With one exception, the valve body **65***a* and the valve member **67***a* and all parts of the booster pump **25***a* therebelow are identical with the corresponding parts of the booster pump **25** so that a detailed description thereof is unnecessary, the exception mentioned being that the valve body **65***a* is provided with exhaust passages **71***a*, only one of which is shown, which communicate with the annular space **62***a*.

As in the case with the annular space **62** in the booster pump **25**, the annular space **62***a* receives the well fluid discharged from the pump cylinders of the booster pump **25***a*, such well fluid flowing upwardly through the annular space **62***a* into the longitudinal inlet ports **45***a* leading into the main fluid-operated pump **24**. Thus, since the exhaust passages **71***a* for spent fluid from the motor cylinder of the booster pump **25***a* communicate with the annular space **62***a*, it will be apparent that the spent operating fluid is mixed with the well fluid discharged by the booster pump **25***a* before such well fluid is delivered to main fluid-operated pump **24**, rather than being mixed with the fluid discharged by the main pump as in the case of the previously described embodiment. The mixture of spent operating fluid from the motor cylinder of the booster pump **25***a* and the well fluid pumped by the booster pump is discharged through the discharge valve assembly **40** by the fluid-operated pump **24** as in the previous embodiment. From the discharge valve assembly **40**, the fluid discharged by the main pump flows through the longitudinal discharge ports **46***a* and the radial discharge ports **47***a* into the production tubing **22** and thence to the surface.

Although I have disclosed two exemplary embodiments of my invention herein for convenience in disclosing same, it will be understood that the invention is not necessarily limited to such embodiments since various changes, modifications and substitutions may be incorporated therein without necessarily departing from the spirit of the invention.

I claim as my invention:

1. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump of the reciprocating type adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for actuating said auxiliary fluid-operated pump so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

2. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump of the reciprocating type adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to the lower end of said pump and extending therebelow and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type; means providing a closed, pressure-maintaining passages communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for actuating said auxiliary fluid-operated pump so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

3. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump of the reciprocating type adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and axially aligned therewith and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for actuating said auxiliary fluid-operated pump so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

4. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump of the reciprocating type adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type; means providing a closed, pressure maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means common to both of said fluid-operated pumps for supplying operating fluid thereto to actuate the same, said auxiliary fluid-operated pump being adapted to be actuated so as to pump

well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port, and said primary fluid-operated pump being adapted to be actuated so as to pump said well fluid from its inlet port to the surface of the ground.

5. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type having motor piston means and a pair of pump cylinders each provided with a pump piston, and having means for connecting said motor piston means to said pump pistons, said pump pistons being connected in tandem, said auxiliary fluid-operated pump including annular intake passage means communicating with said intake port and common to and communicating with said pump cylinders for conveying well fluid from said intake port to said pump cylinders, and said auxiliary fluid-operated pump including discharge passage means common to and communicating with said pump cylinders and communicating with said discharge port for conveying fluid discharged from said pump cylinders to said discharge port; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for actuating said auxiliary fluid-operated pump so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

6. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type having motor piston means and having pump piston means connected to and of larger diameter than said motor piston means so as to pump a large volume of well fluid at a low fluid pressure; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for actuating said auxiliary fluid-operated pump so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

7. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump adapted to be disposed in a well to pump well fluid to the surface of the ground, said primary fluid-operated pump having a central axis and including an inlet port; auxiliary pumping means secured relative to said primary fluid-operated pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and passage means extending along said central axis of said primary fluid-operated pump for conducting operating fluid under relatively high pressure through said primary fluid-operated pump to said auxiliary fluid-operated pump to actuate the latter so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

8. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump of the reciprocating type adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type adapted to be actuated by an operating fluid supplied thereto; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for conducting said operating fluid to said auxiliary fluid-operated pump to actuate it so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port, spent operating fluid from said auxilary fluid-operated pump being discharged into said well fluid being pumped thereby.

9. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump of the reciprocating type adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type adapted to be actuated by an operating fluid supplied thereto; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for conducting said operating fluid to said auxiliary fluid-operated pump to actuate it so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port, spent operating fluid from said auxiliary fluid-operated pump being discharged in the well fluid discharged from said primary fluid-operated pump.

10. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type connected to one end of said primary fluid-operated pump and provided with a motor cylinder with a motor piston therein, provided with a plurality of axially aligned pump cylinders each having a pump piston therein, and provided with means for operatively connecting said pump pis-

tons to said motor piston, said auxiliary fluid-operated pump including annular intake passage means communicating with said intake port and common to and communicating with said pump cylinders for conveying well fluid from said intake port to said pump cylinders, and said auxiliary fluid-operated pump including discharge passage means common to and communicating with said pump cylinders and communicating with said discharge port for conveying fluid discharged from said pump cylinders to said discharge port; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for conveying operating fluid from said end of said primary fluid-operated pump to said auxiliary fluid-operated pump to actuate the latter so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

11. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump adapted to be disposed in a well to pump well fluid to the surface of the ground, said primary fluid-operated pump including motor and pump pistons and rod means connected to said motor and pump pistons, and said primary fluid-operated pump including an inlet port, said motor and pump pistons and said rod means having axial passage means therethrough adapted to communicate at its upper end with a source of operating fluid under pressure; and auxiliary pumping means secured relative to the lower end of said primary fluid-operated pump and extending therebelow and including an intake port adapted to communicate with the well fluid in the well and a discharge port, said auxiliary pumping means including means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port, and including an auxiliary fluid-operated pump of the reciprocating type which communicates with the lower end of said axial passage means to receive operating fluid under pressure for actuating said auxiliary fluid-operated pump so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

12. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump adapted to be disposed in a well to pump well fluid to the surface of the ground, said primary fluid-operated pump having motor and pump pistons and having rod means connected to said motor and pump pistons, said primary fluid-operated pump being adapted to be connected at its upper end to a source of operating fluid under pressure and having a balance chamber at its lower end, said rod means being adapted to extend at its upper end into said source of operating fluid under pressure and extending at its lower end into said balance chamber, said motor and pump pistons and said rod means having axial passage means therethrough adapted to communicate at its upper end with said source of operating fluid under pressure and communicating at its lower end with said balance chamber, said primary fluid-operated pump further including an inlet port; and auxiliary pumping means secured relative to the lower end of said primary fluid-operated pump and extending therebelow and including an intake port adapted to communicate with the well fluid in the well and a discharge port, said auxiliary pumping means including means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port, and including an auxiliary fluid-operated pump of the reciprocating type which communicates with said balance chamber to receive operating fluid under pressure from said balance chamber to actuate said auxiliary fluid-operated pump so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port.

13. A fluid-operated pumping device as defined in claim 12 wherein said auxiliary fluid-operated pump is provided with a balance chamber at its lower end, said auxiliary fluid-operated pump including motor piston means and pump piston means and rod means connecting said motor and pump piston means, said rod means of said auxiliary fluid-operated pump extending at its upper end into said balance chamber of said primary fluid-operated pump and extending at its lower end into said balance chamber of said auxiliary fluid-operated pump, said motor and pump piston means and said rod means of said auxiliary fluid-operated pump having axial passage means therethrough providing fluid communication with said balance chamber of said primary fluid-operated pump and said balance chamber of said auxiliary fluid-operated pump.

14. In a fluid-operated pumping device, the combination of: a primary fluid-operated pump of the reciprocating type adapted to be disposed in a well to pump well fluid to the surface of the ground, including an inlet port; auxiliary pumping means secured relative to said pump and including an intake port adapted to communicate with the well fluid in the well, and having a discharge port, said auxiliary pumping means including an auxiliary fluid-operated pump of the reciprocating type adapted to be actuated by an operating fluid supplied thereto; means providing a closed, pressure-maintaining passage communicating only with said inlet and discharge ports so as to maintain the fluid pressure in said inlet port substantially equal to that in said discharge port; and means for conducting said operating fluid to said auxiliary fluid-operated pump to actuate it so as to pump well fluid from the well into said inlet port at a fluid pressure higher than that in said intake port, spent operating fluid from said auxiliary fluid-operated pump being discharged into said well fluid being pumped by one of said pumps.

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