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METHOD OF AND APPARATUS FOR HYDRAULIC PUMPING

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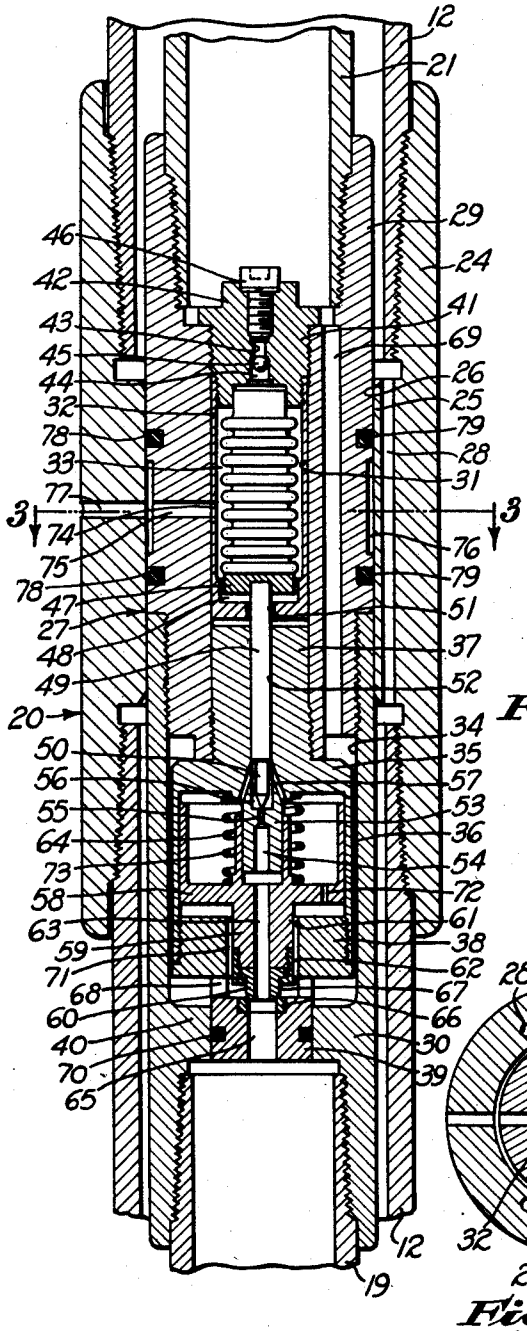


Fig. 2

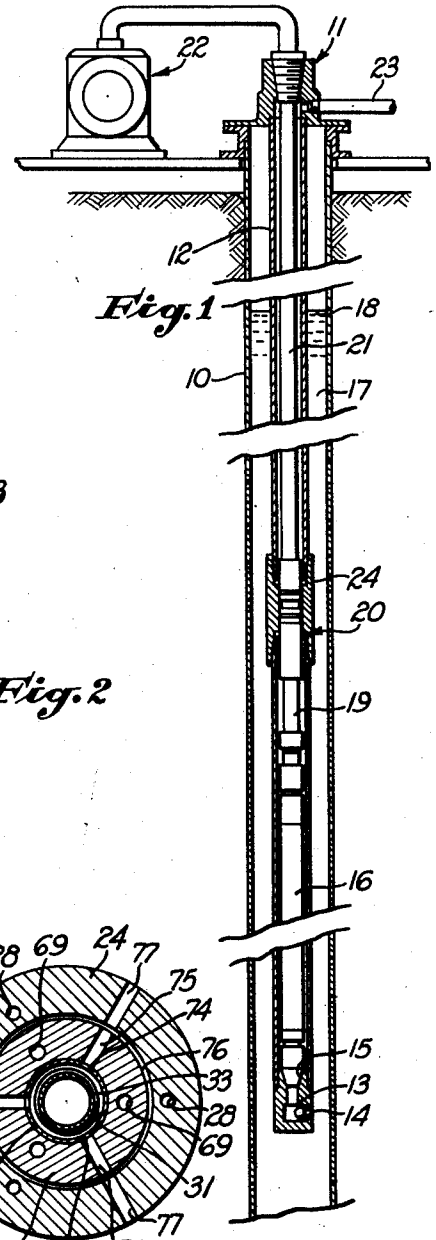


Fig. 1

Fig. 3

INVENTOR:
CLARENCE J. COBERLY
By His Attorneys
HARRIS, KIECH, FOSTER & HARRIS
By

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METHOD OF AND APPARATUS FOR HYDRAULIC PUMPING

Clarence J. Coberly, Los Angeles, Calif., assignor, by mesne assignments, to Dresser Equipment Company, Cleveland, Ohio, a corporation of Ohio

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This invention relates to methods of and apparatus for hydraulic pumping, and more particularly to a method and governing apparatus for controlling the operation of fluid-operated pumps in wells and other bodies of liquid having quickly variable fluid levels.

While my invention has particular application to the oil industry and will be described in connection with use in that industry, it is to be understood that I do not intend to be limited to that particular use, as obviously the invention may be applied to other industries and usages in which it is desirable to operate a pump to maintain a fluid level between predetermined limits.

Fluid operated pumps for use in deep wells ordinarily include a fluid motor with a pump unit operatively connected thereto adapted to pump oil, or other well fluid, from the well up through a production tubing leading to the top of the well. For actuating the fluid motor, operating fluid such as oil is pumped under relatively high pressure from the top of the well downwardly through a supply tubing which connects to the fluid motor. Such fluid operated pumps are ordinarily operated at relatively great depths in oil wells, under conditions which are not observable from the ground surface and which may produce fluctuation in the pumping load, causing the pump to race when the load lightens and to incur hydraulic shock when the pump is partially filling with fluid. To prevent racing, shock, and other detrimental effects, such as reversed hydraulic pressure surges forcing production fluid into the working parts of the pump and the fluid motor, a governor mechanism may be provided in the supply tubing conveying operating fluid to the pump which will immediately control the rate of flow to the fluid motor and prevent it from exceeding a safe limit of speed. In my Patents No. 2,119,736, issued June 7, 1938, for "Governed Fluid Operated Pump"; No. 2,119,737, issued June 7, 1938, for "System of Operating Fluid Operated Pumps"; and No. 2,266,356, issued December 16, 1941, for "Automatically Governed Pump," I have disclosed governors for controlling the rate of flow of operating fluid, which are responsive to changes of rate of flow of the operating fluid to effect such control, such rate of flow being in turn related to the pump load.

A common cause of changes in the pump load is lowering of the fluid level in the well casing to the point where gas enters the pump, with the fluid or instead of fluid. This will cause the pump to race unless some mechanism such as a governor intervenes to reduce the flow of the operating

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fluid to the pump. Governors of the type described in my above-referred to patents act responsively to the effect upon the governor produced by an increased rate of flow of operating fluid to the pump rather than responsively to the cause of such increased rate of flow, and consequently, cannot be effective until the flow increase and racing of the pump is actually started, which may be detrimental to the mechanism of the pump or to the operation of the pumping system.

It is therefore a primary purpose of my invention to provide a method of hydraulic pumping in which the rate of operation of a fluid operated pump is controlled in accordance with the depth of the liquid available to be pumped so as to prevent that depth from falling below a desired minimum.

It is another purpose of my invention to provide a flow governing device for the operating fluid of fluid operated pumps which is responsive directly to conditions affecting the operation of the pump and so is effective to control the operation of the pump before such conditions can produce detrimental effects.

It is a further purpose of the invention to provide a fluid flow governor responsive to the fluid level in a well to control the pumping rate of a hydraulic pump when the fluid level in the well reaches a predetermined point.

It is another purpose of my invention to provide a fluid flow governor for a fluid operated pump which will prevent the pump from being operated at a speed in excess of the capacity of the well and thus prevent the pump from pumping gas with attendant damage to the pump parts.

Still another purpose of my invention is to provide a fluid flow governor of the class described in which a valve controlling the flow of operating fluid is pilot-operated by a fluid-level actuated valve and is therefore very sensitive to fluid level changes.

A further purpose of my invention is to provide a governor of the class described having a Sylphon element which may be precharged to be responsive to a predetermined fluid pressure in the well and which is connected to a pilot valve which in turn governs the operation of a main valve, so that when the well pressure exceeds the predetermined pressure, the pilot valve will be held open and will in turn hold the main valve open.

Another purpose of my invention is to provide a governor of the class described having a Sylphon controlled valve which may be readily charged to any desired pressure and which is

made in a unit assembly readily interchangeable with other units set for different pressures for operative connection to a fluid flow control valve.

Still another purpose of my invention is to provide a governor of the class described having a side passage communicating between a Sylphon element within the governor and the well bore and having means for sealing the operating fluid supply line from said passage.

Other objects and advantages will appear in the following specification and in the drawing, in which:

Fig. 1 is a diagrammatic utility view, partly in section, of my invention installed in a well;

Fig. 2 is a vertical sectional view of the governor of my invention showing the valves in their closed position; and

Fig. 3 is a horizontal sectional view taken on the line 3—3 of Fig. 2, and on a reduced scale.

Referring to Fig. 1 of the drawings, I show a well casing 10 perforated at its lower end as is common in the art to permit well liquid to flow thereinto from the well formation, and having a casing head 11 provided at its upper end. Suspended from the casing head 11 is a production tubing 12 having secured at its lower end an inlet check valve member 13 provided with an inlet opening 14 communicating with a conical pump seat 15 adapted to receive in seating relation the lower tapered end of a fluid operated pump 16. The inlet check valve member 13 is so arranged in the inlet opening 14 as to permit well fluid to flow through the inlet check valve member into the fluid operated pump but to prevent a reverse flow thereof. The fluid operated pump may be of any suitable type, but I prefer to use a fluid operated pump such as is shown in my above Patent No. 2,119,736, to which reference is hereby made for the details of construction thereof.

For illustrative purposes, a body of well liquid 17 is shown within the well casing 10, having a surface level 18, and it is will be understood that the liquid 17 is to be pumped by the pump 16 and that the surface level 18 will vary in height above the inlet opening 14 according to the relative rates of influx through the well casing 10 and of output of the pump 16.

Connected to the upper end of the fluid operated pump 16 is an inlet tubing 19 to which is connected the flow governor 20 of my invention at a height normally below the surface level 18. Connected to the upper end of the flow governor 20 is a string of power tubing 21 which extends through the casing head 11 to a surface pumping mechanism 22 of any suitable type adapted to pump an operating fluid, such as clean oil, under high pressure downwardly through the power tubing 21, the flow governor 20, and the inlet tubing 19 to the fluid operated pump 16 to actuate the same. Also connected to the casing head 11 and communicating with the production tubing 12 is a discharge pipe 23 adapted to convey fluid discharging therethrough to a point of discharge or use (not shown).

A special coupling 24 connects upper and lower units of the production tubing 12 at the level of the flow governor 20 and has, between said upper and lower units, an inwardly extending thickened portion 25, forming a guide surface 26, of sufficient diameter to allow the pump 16 to pass downwardly therethrough to rest upon the conical pump seat 15, and fitting slidably upon a housing 27 which encases the hereafter described members of the governor 20. Vertical passages 28 in the thickened portion 25 of the special coupling 24 connect the interiors of the upper and lower units of the production tubing 12 and permit the pump 16 to pump well liquid upwardly past the housing 27.

The housing 27 comprises an upper coupling member 29 threadedly secured to the supply tubing 21, and a lower coupling member 30 threadedly secured to the inlet tubing 19, the coupling members 29 and 30 being threadedly secured to each other and being externally proportioned to fit closely in the thickened portion 25 of the special coupling 24. The upper coupling member 29 has an internal bore 31, in the upper part of which is disposed a cylinder 32, housing a bellows element 33, of the type known as a Sylphon and longitudinally expansible and contractible in response to decrease and increase of external pressure. The lower coupling member 30 has an internal bore 34 housing a cylinder 35 proportioned externally to leave an annular passage 36 between its outer surface and the inner surface of the coupling member 30 and having an extension 37 by which it is threadedly secured in the lower part of the bore 31 of the upper coupling member 29. A cylinder head 38 is threadedly secured in the lower end of the cylinder 35 and is provided with an extension 39 closely fitting within a guide collar 40 formed on the inner surface of the lower coupling member 30. The guide collar 40 serves to keep the cylinder 35 in alignment within the bore 34, to maintain uniform width of the annular passage 36.

The bellows element 33 is secured, as by soldering or brazing, to a head 41 which is threadedly secured to the cylinder 32 and to the upper coupling 29 and is provided with a nut extension 42 by which the cylinder 32 and the bellows element 33 contained therein may be detached from the housing 27 by application of a suitable wrench. The head 41 has a bore 43 provided with a check valve chamber 44 in which is a ball check 45, and the bore is closed by a screw plug 46, which may be removed to permit the bellows element 33 to be filled with gas to a desired pressure, the ball check 45 retaining the gas while the plug 46 is being replaced. At its lower end, the bellows element 33 is secured, as by soldering or brazing, to a plunger 47 proportioned to provide a working space 48 within the cylinder 32 to permit expansion and contraction of the bellows element 33. The plunger 47 has secured to it a valve stem 49 of a needle valve 50 which extends downwardly through an orifice 51 in the bottom of the cylinder 32 and through a bore 52 in the extension 37 of the cylinder 35. The needle valve 50 is thus removable from the housing 27 along with the bellows element 33.

The cylinder 35 has a central boss 53 extending downwardly thereinto and has a bore 54 communicating with the bore 52 and connected therewith by a restricted orifice 55 which forms a seat for the needle valve 50. The lower portion of the bore 52 forms a valve chamber 56 around the needle valve 50 and is connected to the interior of the cylinder 35 by passages 57.

A cup-shaped main valve piston 58 fits slidably within the cylinder 35 and has a depending extension 59 on its lower face forming a stem for a main valve 60 of the poppet type extending through an opening 61 in the cylinder head 38. The main valve 60 is secured to the extension 59 by a retaining nut 62. The extension 59 has a bore 63 communicating between the lower face of the main valve 60 and the bore 54, the main valve piston 58 being provided with an upwardly

extending guide collar 64 which fits slidably on the boss 53 of the cylinder 35. The extension 39 of the cylinder head 38 has a main discharge passage 65 fitted with a valve seat 66 for the main valve 60 and communicating between a valve chamber 67 in the lower portion of the opening 61 and the inlet tubing 19. Lateral passages 68 communicate between the annular passage 36 and the valve chamber 67, and a plurality of vertical passages 69 in the upper coupling member 29 communicate between the supply tubing 21 and the annular passage 36, thus providing a through flow channel from the supply tubing 21 to the inlet tubing 19, controlled by the main valve 60. To prevent leakage past the main valve 60, the extensions 39 is provided with a sealing ring 70 bearing against the guide collar 40 of the lower coupling member 30.

The extension 59 of the main valve piston 58 fits loosely within the opening 61 of the cylinder head 38 so as to provide an annular channel 71 leading from the valve chamber 67 to the interior of the cylinder 35 below the piston 58. The piston 58 is provided with a restricted orifice 72, thus providing a by-pass around the main valve 60 by way of the upper portion of the cylinder 35, passages 57, the needle valve chamber 56, orifice 55 and bores 52 and 63. The orifice 72 provides a restriction in this bypass, so that opening of the needle valve 50 will establish a limited flow of fluid through the by-pass, and this limited flow will set up a pressure gradient acting on the piston 58 tending to move it upwardly. The piston 58 is urged downwardly, tending to hold the main valve 60 closed, by a spring 73 bearing against the top of the piston and against the upper portion of the cylinder 35.

The cylinder 32 is provided with a plurality of radial openings 74 which communicate with radial passages 75 in the upper coupling member 29. A relatively wide annular channel 76 is formed in the outer surface of the upper coupling member 29, with which the passages 75 communicate, and a plurality of radial passages 77 in the special coupling 24 complete the channel through which liquid in the well casing 10 may enter the cylinder 32. Thus, the fluid pressure in the well at the level of the passages 77 is imposed upon the exterior of the bellows element 33. The annular channel 76 provides some leeway in the vertical placement of the housing 27 relatively to the special coupling 24, in a zone determined by placement of the pump 16 on the conical pump seat 15 and by the length of the inlet tubing 19. To isolate the radial passages 75 and 77 from the upper and lower units of the production tubing 12, which will contain liquid at a higher pressure than the pressure in the well casing 10, the outer surface of the upper coupling member 29 is provided with grooves 78 above and below the annular channel 76, and the grooves 78 are provided with sealing rings 79 which seal the housing 27 to the special coupling 24 while permitting relative vertical movement thereof.

Prior to installation of the governor 20 in the well, the bellows element 33 is charged with gas through the check valve 44 to such pressure that it will resist compression until the external pressure to which it is subjected is the pressure developed hydrostatically by a column of liquid in the well casing 10 attaining a desired height above the level of the passages 77.

In operation, and when the governor 20 is installed in the well as shown in Fig. 1, when the surface level of the liquid in the well casing 10 is at a height greater than the desired height for which the bellows element 33 is charged the pressure of the well liquid entering the cylinder 32 through the radial passages 77, channel 76, and radial passages 75 will compress the bellows element 33 and cause it to raise the plunger 47 and valve stem 49 to which the needle valve 50 is secured. The needle valve 50 will thus be raised from its seat in the orifice 55, permitting high pressure operating fluid to flow from the power tubing 21, passages 69, annular passage 36, lateral passages 68, and valve chamber 67, through the by-pass comprising the annular channel 71, the lower portion of the cylinder 35, orifice 72, upper portion of the cylinder 35, passages 57, needle valve chamber 56, orifice 55, and bores 54 and 63, to the discharge passage 65 and thence to the inlet tubing 19 and the pump 16. Flow of the high pressure fluid from the lower portion of the cylinder 35 to the upper portion thereof through the orifice 72 will create a pressure gradient across the piston 58, tending to cause the piston to rise against the resistance of the spring 73 and to raise the main valve 60 from the valve seat 66. This will permit the high pressure operating fluid to flow directly from the valve chamber 67 to the pump 16 and cause the pump to operate. Liquid is then pumped from the well casing 10 through the production tubing 12 to the discharge pipe 23, the liquid passing around the governor 20 through the passages 28 in the special coupling 24.

Conversely, when the surface level 18 of the liquid in the well casing 10 falls below the desired height corresponding to the internal pressure in the bellows element 33, the bellows element will expand, causing the needle valve 50 to close and to cut off the flow of operating fluid through the above described by-pass. Hydraulic pressure on the faces of the piston 58 will then be equalized, and the spring 73 will move the piston downwardly, closing the main valve 60 and cutting off the supply of operating fluid to the pump 16.

As a bellows element such as is herein described expands and contracts responsively to changes in the pressure differential on its external and internal surfaces occurring over a predetermined range rather than at a predetermined degree, the lifting and lowering of the needle valve 50 will not be abrupt, but will be gradual, following changes in the height of the liquid in the well casing 10 above the passages 77. Consequently, the flow through the orifice 72 will be gradually changed, the resultant pressure gradient across the piston 58 will gradually change, and the main valve 60 will be raised and lowered gradually. The supply of operating fluid to the pump 16 will therefore be regulated to maintain the pump at an operating speed tending to pump liquid from the well casing 10 at the same rate that liquid flows into the casing and to maintain the hydrostatic pressure at the radial passages 77 substantially constant so long as the inflow of liquid into the well casing is constant. Any increase in the rate of inflow of liquid into the well casing will permit an increased flow of operating fluid to the well pump 16 and a corresponding increase in the rate of pumping, and a decrease in the rate of inflow will cause a corresponding decrease in the rate of pumping, even to the point of shutting down the pump. Liquid in the well-casing 10 is thus always maintained at a height above the pump 16 sufficient to provide a hydrostatic pres-

sure-head on the pump and to prevent the pump from pumping gas and consequently racing.

The cylinder **32**, bellows element **33**, needle valve **50**, and head **41**, form a unit which is readily removable from the upper coupling member **29** by unscrewing the head **41** from the member **29**, and may be replaced by a similar unit charged to any desired pressure, or may be adjusted to any desired pressure by admission or release of gas through the check valve chamber **44**.

Various possible changes in the arrangements and proportions of the parts and passages of my invention will be apparent to any person skilled in the art and do not depart from the spirit of my invention.

I claim as my invention:

1. In a fluid operated pumping system for wells, the combination of: a fluid operated pump adapted to be installed in a well; power tubing communicating with said pump and adapted to convey operating fluid under high pressure downwardly through said well to actuate said pump; production tubing communicating with said pump and adapted to convey the discharge from said pump upwardly through the well; a fluid flow governor disposed in the line of said power tubing and adapted to control the flow of said operating fluid therethrough; and pressure responsive means for controlling the operation of said governor in response to variations in the level of liquid in the well, including a fluid passage communicating between the interior of said governor and the exterior of said production tubing at a point adjacent to said governor.

2. In a fluid operated pumping system for wells, the combination of: a fluid operated pump adapted to be installed in a well; power tubing adapted to convey operating fluid under high pressure downwardly through said well to actuate said pump; production tubing concentric with said power tubing and adapted to convey the discharge from said pump upwardly through the well; collar means in the line of said production tubing and having a lateral fluid passage communicating between the interior and exterior of said production tubing, said colar means also having a longitudinal passage communicating between the upper and lower ends thereof so as to permit said pump discharge to flow upwardly therethrough; and a fluid flow governor disposed within said collar means and connected in the line of said power tubing and being adapted to control the flow of said operating fluid therethrough, said governor being provided with a fluid control passage adapted to communicate with said lateral fluid passage to permit the entry of well fluid into said governor.

3. In a fluid operated pumping system for wells the combination of: a fluid operated pump adapted to be installed in a well; power tubing adapted to convey operating fluid under high pressure downwardly through said well to actuate said pump; production tubing concentric with said power tubing and adapted to convey the discharge from said pump upwardly through the well; collar means in the line of said production tubing and having a lateral fluid passage communicating between the interior and exterior of said production tubing, said collar means also having a longitudinal passage communicating between the upper and lower ends thereof so as to permit said pump discharge to flow upwardly therethrough; a fluid flow governor disposed within said collar means and connected in the line of said power tubing and being adapted to control the flow of said operating fluid therethrough, said governor being provided with a fluid control passage adapted to communicate with said lateral fluid passage to permit the entry of well fluid into said governor; and fluid sealing means disposed between said governor and said collar means on each side of said fluid control and lateral fluid passages.

4. In a device adapted for connection to a pair of concentric tubings, the combination of: collar means adapted to be connected to the outer one of said tubings, said collar means having a lateral fluid passage therethrough and having a longitudinal fluid passage therethrough communicating between the upper and lower ends thereof; and a fluid flow governor disposed within said collar means and adapted to be connected to the inner one of said tubings, said governor being adapted to control a flow of fluid through said inner one of said tubings, said governor being provided with a fluid control passage adapted to communicate with said lateral fluid passage.

5. In a device adapted for connection to a pair of concentric tubings, the combination of: collar means adapted to be connected to the outer one of said tubings, said collar means having a lateral fluid passage therethrough and having a longitudinal fluid passage therethrough communicating between the upper and lower ends thereof; a fluid flow governor disposed within said collar means and adapted to be connected to the inner one of said tubings, said governor being adapted to control a flow of fluid through said inner one of said tubings, said governor being provided with a fluid control passage adapted to communicate with said lateral fluid passage; and fluid sealing means disposed between said governor and said collar means and adapted to form a fluid-tight seal therebetween both above and below said fluid control and lateral fluid passages.

6. In a governor for controlling the rate of flow of operating fluid to a fluid operated pump adapted to operate in a well below the surface level of a body of liquid to be pumped and having a production conduit for said liquid and a supply conduit for said operating fluid, the combination of: main valve means for controlling the rate of flow of operating fluid through said governor; pilot valve means for causing said main valve means to open and to close; and means responsive to fluctuations in the surface level of said body of liquid in the well for actuating said pilot valve means, including an element connected to said pilot valve means and exposed to said body of liquid.

7. In a governor for controlling the rate of flow of operating fluid to a fluid operated pump adapted to operate in a well below the surface level of a body of liquid to be pumped and having a production conduit for said liquid and a supply conduit for said operating fluid, the combination of: main valve means for controlling the rate of flow of operating fluid through said governor; pilot valve means adapted by opening and closing respectively to cause said main valve means to open and to close; and means responsive to fluctuations in the surface level of said body of liquid in the well for opening and closing said pilot valve means, including an element connected to said pilot valve means and exposed to said body of liquid.

8. In a governor for controlling the rate of flow of operating fluid to a fluid operated pump adapted to operate below the surface level of a body of liquid to be pumped and having a pro-

duction conduit for said liquid and a supply conduit for said operating fluid, the combination of: a main valve for controlling the flow of operating fluid through said governor; means forming a by-pass for by-passing said fluid past said main valve; means responsive to flow of said fluid through said by-pass for opening said main valve; a pilot valve adapted to control the flow of said fluid through said by-pass; and pressure-actuated means responsive to hydrostatic pressure in said body of liquid and operatively connected to said pilot valve for opening said pilot valve in response to an increase in said hydrostatic pressure.

9. In a governor for controlling the rate of flow of operating fluid to a fluid operated pump adapted to operate below the surface level of a body of liquid to be pumped and having a production conduit for said liquid and a supply conduit for said operating fluid, the combination of: a main valve for controlling the flow of operating fluid through said governor; means responsive to the establishment of a limited flow through said governor for opening said main valve; a pilot valve adapted to establish a limited flow of said fluid through said governor; and pressure-actuated means connected to said pilot valve and responsive to an increase in hydrostatic pressure in said body of liquid to open said pilot valve and responsive to a decrease in said pressure to close said pilot valve.

10. A governor for controlling the flow in the fluid supply line of a fluid operated pump adapted to be immersed in a body of liquid to be pumped, including: two valves for regulating the flow of said pressure fluid and so arranged that the flow therethrough is in parallel, one of said valves being adapted to be opened by the establishment of flow in the flow channel of the other of said valves; a bellows element operatively connected to said other of said valves, and responsive to an increase and a decrease in hydrostatic pressure in said body of liquid within a predetermined range for respectively opening and closing said other valve; and passage means communicating between said bellows element and said body of liquid to be pumped for communicating the pressure in said body of liquid to said bellows element.

11. A governor for controlling the flow in the fluid supply line of a fluid operated pump adapted to be immersed in a body of liquid to be pumped, including: a main valve for controlling the flow of operating fluid through said governor; means forming a by-pass for by-passing said fluid past said main valve; a piston in said by-pass operatively connected to said main valve and adapted to open said main valve responsively to a predetermined fluid pressure drop in said by-pass; spring means urging said main valve towards its closed position in counter-action to said pressure drop; a pilot valve in said by-pass adapted to regulate said pressure drop; a bellows element operatively connected to said pilot valve for opening and closing said pilot valve in response respectively to an increase and to a decrease in pressure on said bellows element; and housing means for said bellows element defining a passage communicating with the exterior of said element and with said body of liquid whereby hydrostatic pressure in said body of liquid is imposed on said element.

12. A governor for controlling the flow in the fluid supply line of a fluid operated pump in a well and adapted to be immersed in a body of liquid to be pumped, including: a housing adapted to be disposed in a well and having a fluid passage through one wall thereof which communicates

with said body of liquid to be pumped; a pilot valve within said housing; a main valve within said housing in parallel with said pilot valve and adapted to be opened in response to a flow of fluid through said pilot valve; and a bellows element within said housing and operatively connected to said pilot valve and adapted to control the operation of said pilot valve in response to variations in fluid pressure on the exterior of said bellows element, said fluid passage communicating with said exterior of said bellows element.

13. In a governor for controlling the rate of flow of operating fluid to a fluid operated pump adapted to operate below the surface level of a body of liquid to be pumped, said pump communicating with a production conduit for said liquid and a supply conduit for said operating fluid, the combination of: a housing for said governor communicating with said supply conduit and insertable in said production conduit at a predetermined level below the normal surface level of said body of liquid; a bellows element removably secured in said housing and adapted to expand and contract in response to changes in external pressure, said housing and said production conduit having passages communicating with the exterior of said element and with the exterior of said production conduit; and valve means for regulating the flow of fluid through said governor including a valve operatively connected to said bellows element and adapted to open responsively to an increase in pressure on said element.

14. In a governor for controlling the rate of flow of operating fluid to a fluid operated pump adapted to operate below the surface level of a body of liquid to be pumped, said pump communicating with a production conduit for said liquid and a supply conduit for said operating fluid, the combination of: a housing for said governor communicating with said supply conduit and insertable in said production conduit at a predetermined level below the normal surface level of said body of liquid; a bellows element secured in said housing, said bellows element having an opening for receiving a gas charge and a closure for said opening, said closure including a check valve whereby said element may be charged to withstand a predetermined degree of external pressure, said element being adapted to expand and contract in response to changes in external pressure, said housing and said production conduit having registering orifices communicating with the exterior of said element and with the exterior of said production conduit; and valve means for regulating the flow of fluid through said governor including a valve operatively connected to said bellows element and adapted to open responsively to an increase in pressure on said element.

15. A governor for controlling the rate of flow of a fluid to a fluid-operated pump disposed in a well, including: a passage for the fluid; a valve seat encompassing said passage; a valve element adapted to engage said valve seat to close said passage; a piston element connected to said valve element; means for exposing one side of said piston element to fluid pressure obtaining in said passage upstream from said valve seat; means for applying a variable fluid pressure to the opposite side of said piston element; and means exposed to fluid pressure obtaining exteriorly of said governor for varying said variable fluid pressure.

16. In a governor for controlling the rate of flow of a fluid to a fluid-operated pump disposed in a well in a body of liquid to be pumped, the combination of: housing means providing a main

passage and a pilot passage in parallel, said housing means also providing a bellows chamber and further providing a vent passage which connects said bellows chamber to the exterior of said housing means and communicates with said body of liquid to be pumped; a bellows in said bellows chamber; a pilot valve within said housing means and operatively connected to said bellows for controlling flow through said pilot passage; a main valve within said housing means for controlling flow through said main passage; and means for operating said main valve in response to variations in the rate of flow through said pilot passage.

17. A governor as set forth in claim 16 wherein the means last mentioned comprises a piston connected to said main valve, said governor including means providing an orifice which connects the ends of said piston and which forms part of said pilot passage.

18. In a governor adapted to be disposed in a well in a body of liquid to be pumped for controlling the rate of flow of an operating fluid to a fluid-operated pump in said body of liquid to be pumped, the combination of: a cylindrical housing provided with a longitudinal passage therethrough for the fluid; axially movable main valve means within said housing for controlling the rate of flow of fluid through said longitudinal passage; axially movable pilot valve means within said housing and axially aligned with said main valve means for operating said main valve means; and axially movable, pressure actuable means within said housing and axially aligned with said pilot valve means and said main valve means for operating said pilot valve means, said housing being provided with a passage through one wall thereof to expose said pressure actuable means to fluid pressure obtaining exteriorly of said housing in said body of liquid to be pumped.

19. A governor for controlling the rate of flow of operating fluid through a supply line leading to a fluid-operated pump which is adapted to pump liquid from a body of liquid in a well, including: a main valve for regulating the rate of flow of operating fluid through the supply line to the pump; a pilot valve connected in parallel with said main valve so that part of the operating fluid flowing through the supply line to the pump can flow through said pilot valve; pressure actuable means responsive to flow through said pilot valve and connected to said main valve for opening said main valve; and pressure responsive means exposed to the fluid pressure obtaining in the body of liquid in the well exteriorly of the governor and connected to said pilot valve for actuating said pilot valve.

20. In a governor for controlling the operation of a fluid-operated pump which is adapted to pump liquid from a body of such liquid, the combination of: housing means providing a main passage and a by-pass passage in parallel, said housing means being adapted to be disposed in the line of a conduit for delivering operating fluid under pressure to the pump, whereby to permit the operating fluid to flow through said main and by-pass passages; means for varying the rate of flow of operating fluid through said by-pass passage in accordance with variations in the fluid pressure obtaining in the body of liquid at a point adjacent the pump; and means for varying the rate of flow of operating fluid through said main passage in accordance with variations in the flow of operating fluid through said by-pass passage.

21. In a fluid-operated pumping system for wells, the combination of: a fluid-operated pump adapted to be installed in a well; passage means, including a power tubing communicating with said pump, for conveying operating fluid under pressure downwardly through said well to actuate said pump; production tubing communicating with said pump for conveying the discharge from said pump upwardly through the well; and a governor independent of said pump and responsive solely to variations in the level of liquid in the well for controlling the flow of operating fluid through said passage means to said pump, said governor including a valve in said passage means and including a device responsive to variations in the level of liquid in the well for continuously moving said valve as the level of liquid in the well varies.

22. In a governor for controlling the rate of flow of operating fluid under pressure to a fluid-operated pump adapted to operate in a well below the surface of a body of liquid to be pumped and having a production tubing for the pumped liquid and a power tubing for the operating fluid, the combination of: a passage; a main valve in said passage for controlling the rate of flow of operating fluid therethrough; pressure actuable means adapted to have a variable pressure differential applied thereto for operating said main valve; pilot valve means communicating with said pressure actuable means for varying the pressure differential applied thereto so as to move said main valve; and means connected to said pilot valve means and responsive to variations in the level of said body of liquid in the well and exposed to said body of liquid in the well for actuating said pilot valve means.

CLARENCE J. COBERLY.

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