Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 1

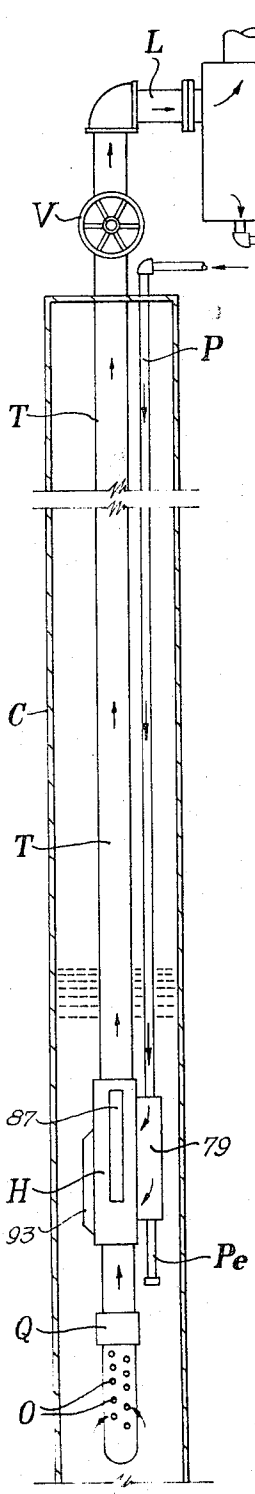


Fig. 1

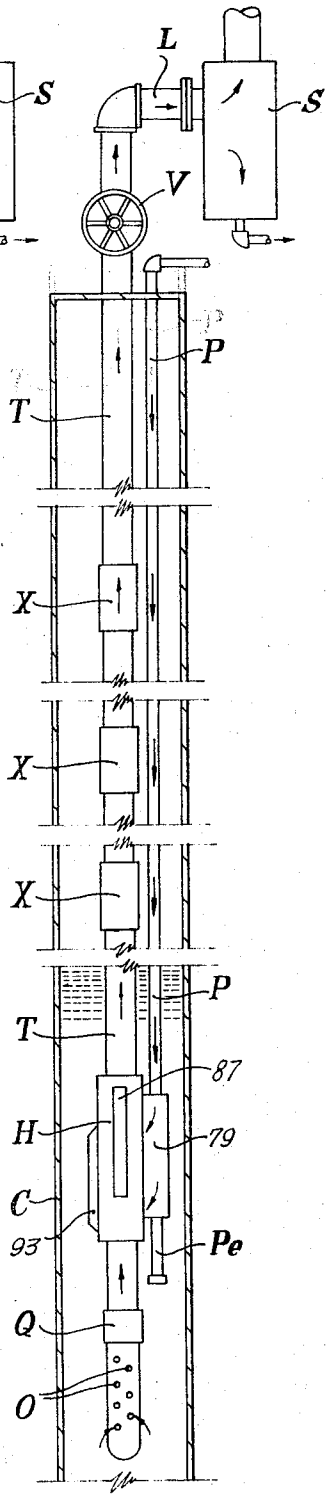


Fig. 2

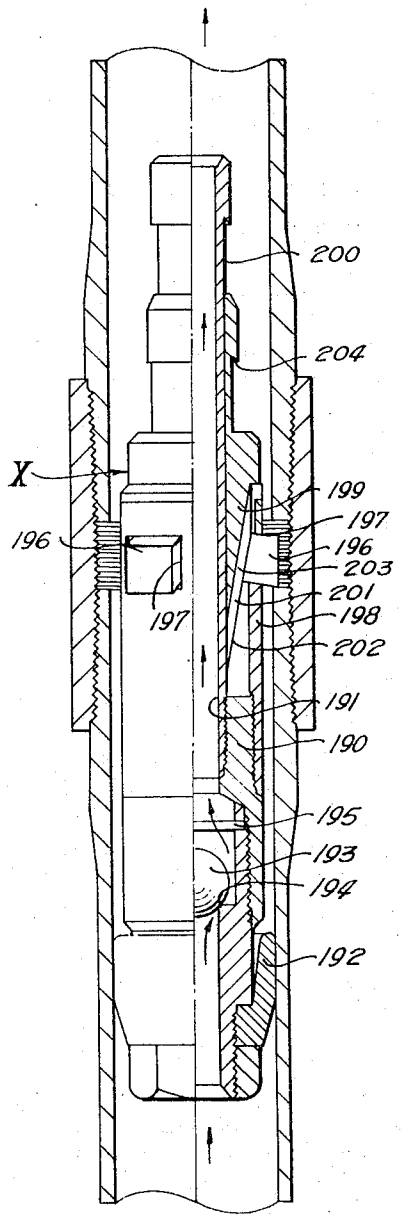


Fig. 34

Samuel J. E. Marshall
INVENTOR.

BY Eastwick Ackley and Walter J. Jaeger

ATTORNEYS

Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 2

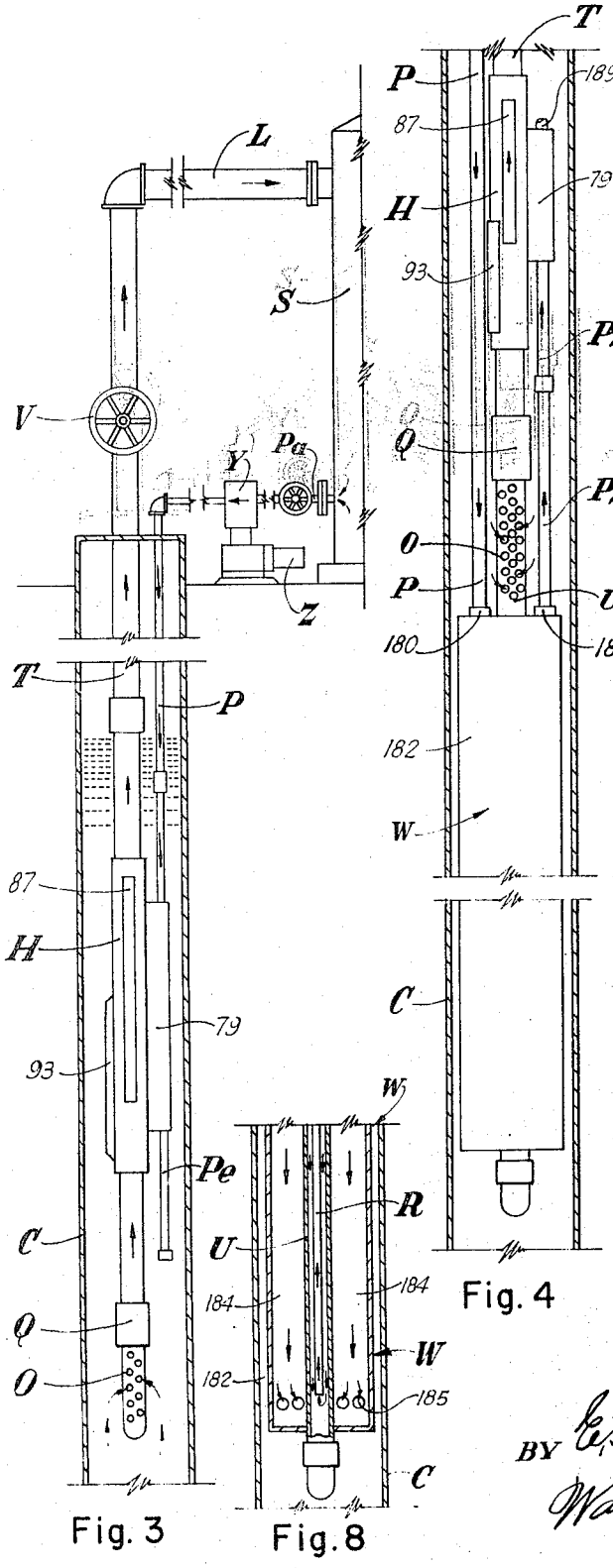


Fig. 3 Fig. 8 Fig. 4

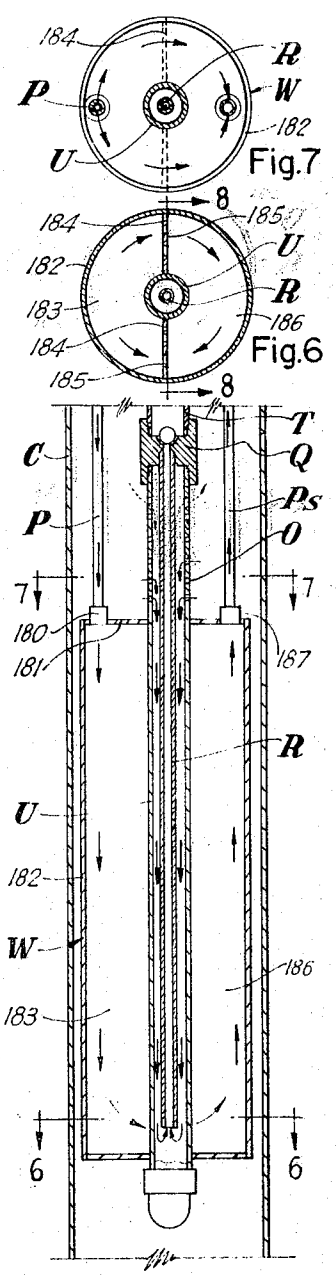


Fig. 5

Samuel J. E. Marshall
INVENTOR.

BY Cushman, Darby & Cushman and Walter J. Jason
ATTORNEYS

Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 3

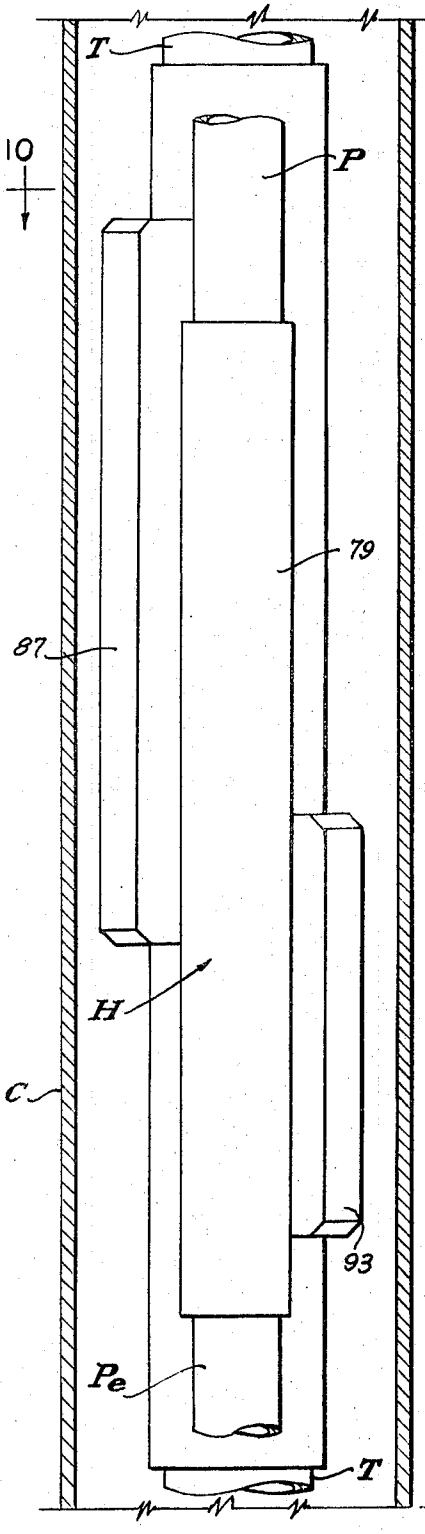


Fig.9

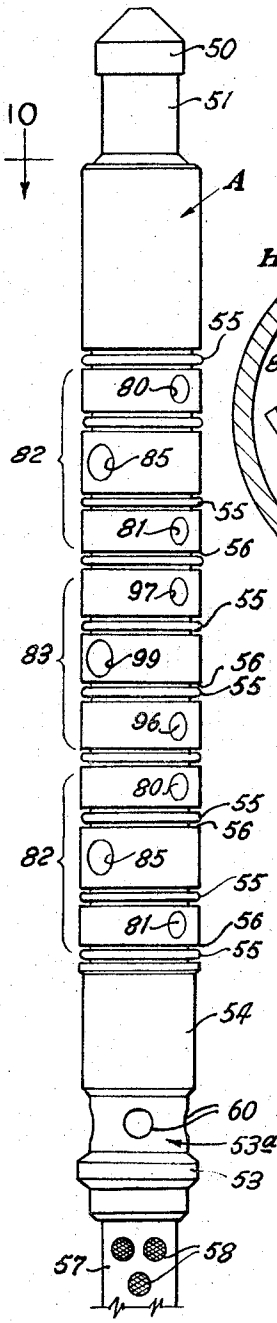


Fig.16

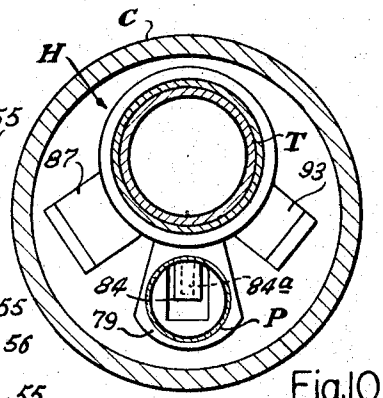


Fig.10

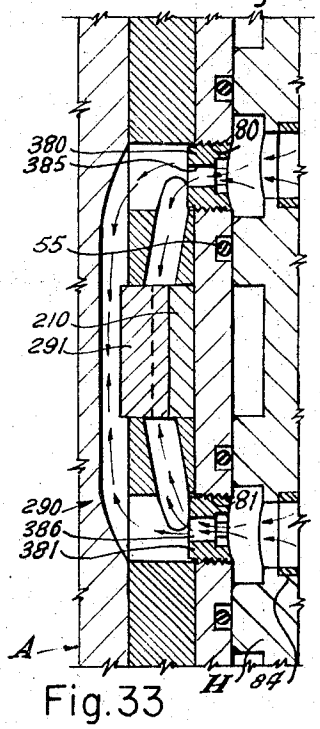


Fig.33

INVENTOR.
Samuel J. E. Marshall
BY Cushman, Darby & Cushman
and
Walter J. Jason
ATTORNEYS

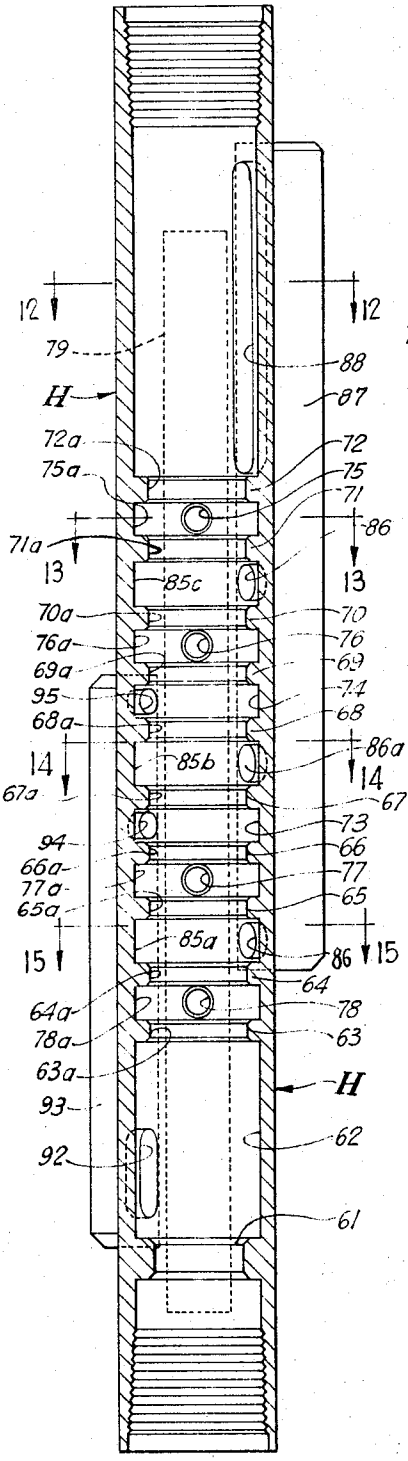


Fig. 11

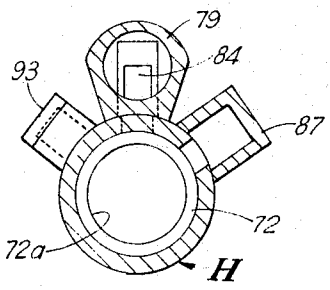


Fig. 12

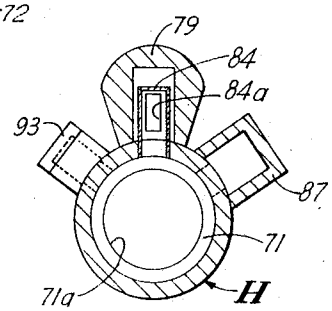


Fig. 13

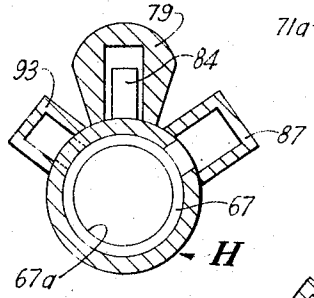


Fig. 14

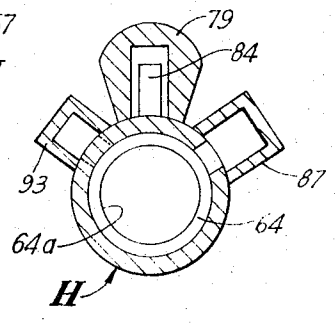


Fig. 15

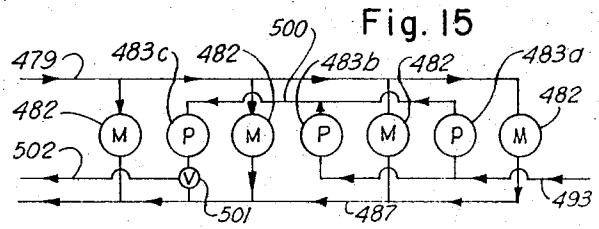


Fig. 35

Samuel J. E. Marshall
INVENTOR.

BY Eastmans Ackley and Walter J. Jaynes

ATTORNEYS

Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 5

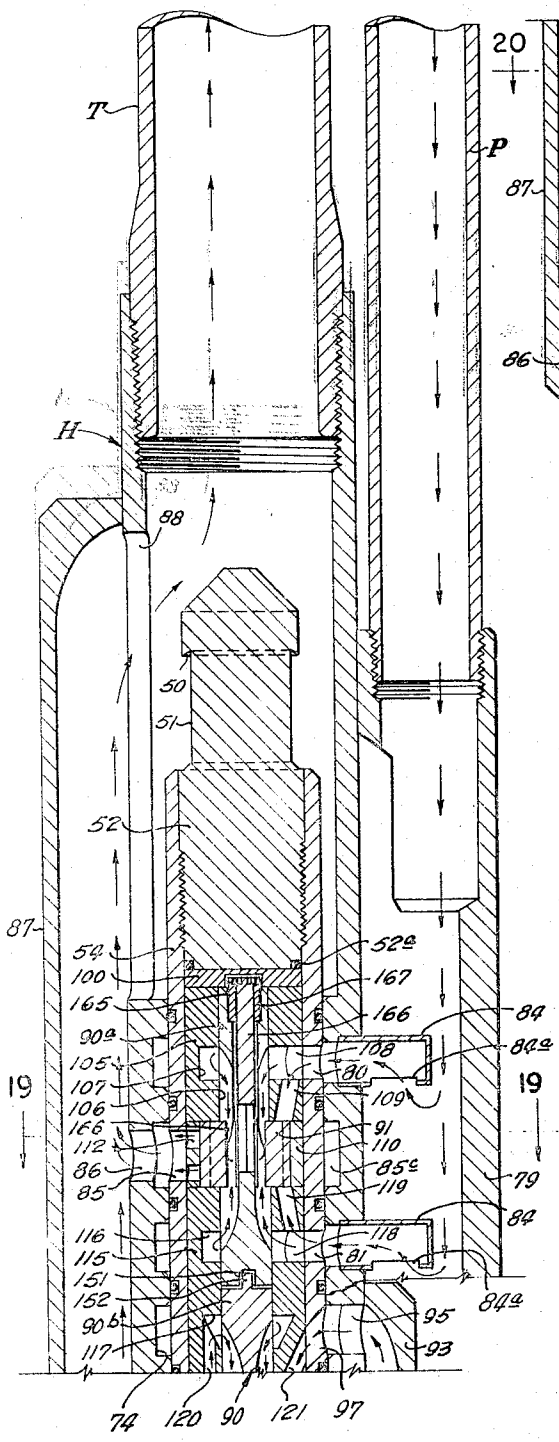


Fig. 17

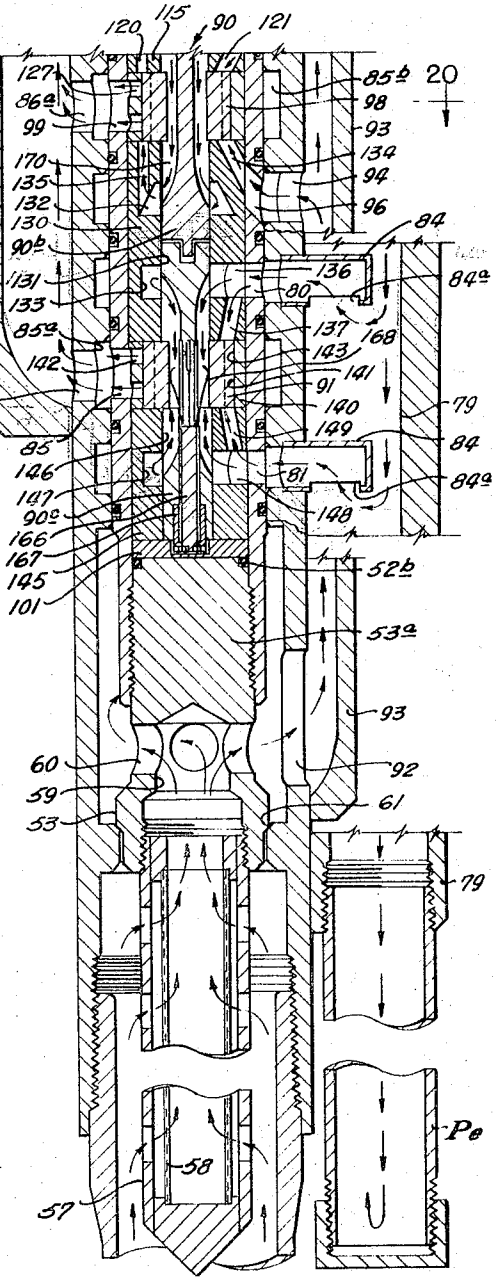


Fig. 18

INVENTOR.
Samuel J. E. Marshall

BY Espy Stevens Ackley and Walter J. Jagger

ATTORNEYS

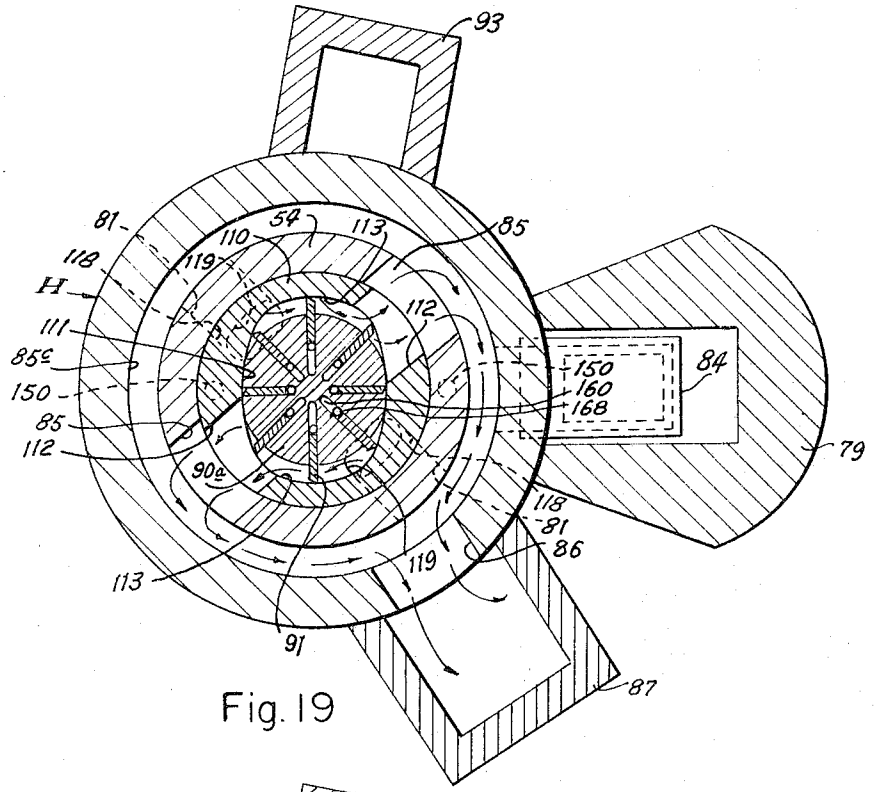


Fig. 19

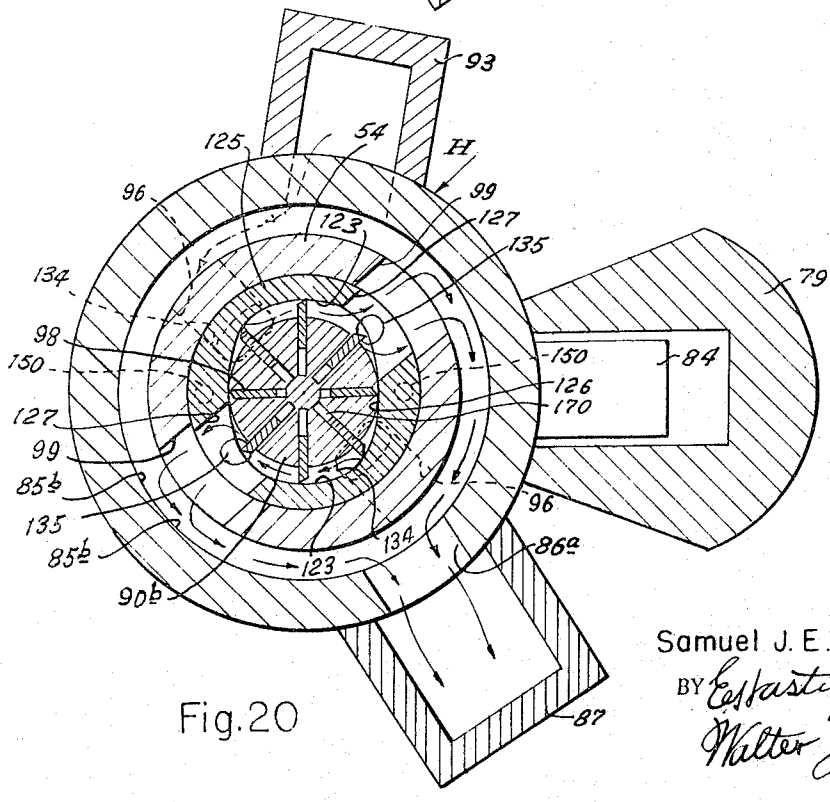


Fig. 20

INVENTOR.
Samuel J. E. Marshall
BY Eastman, Ackley and Walter J. Jaynes
ATTORNEYS

Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 7

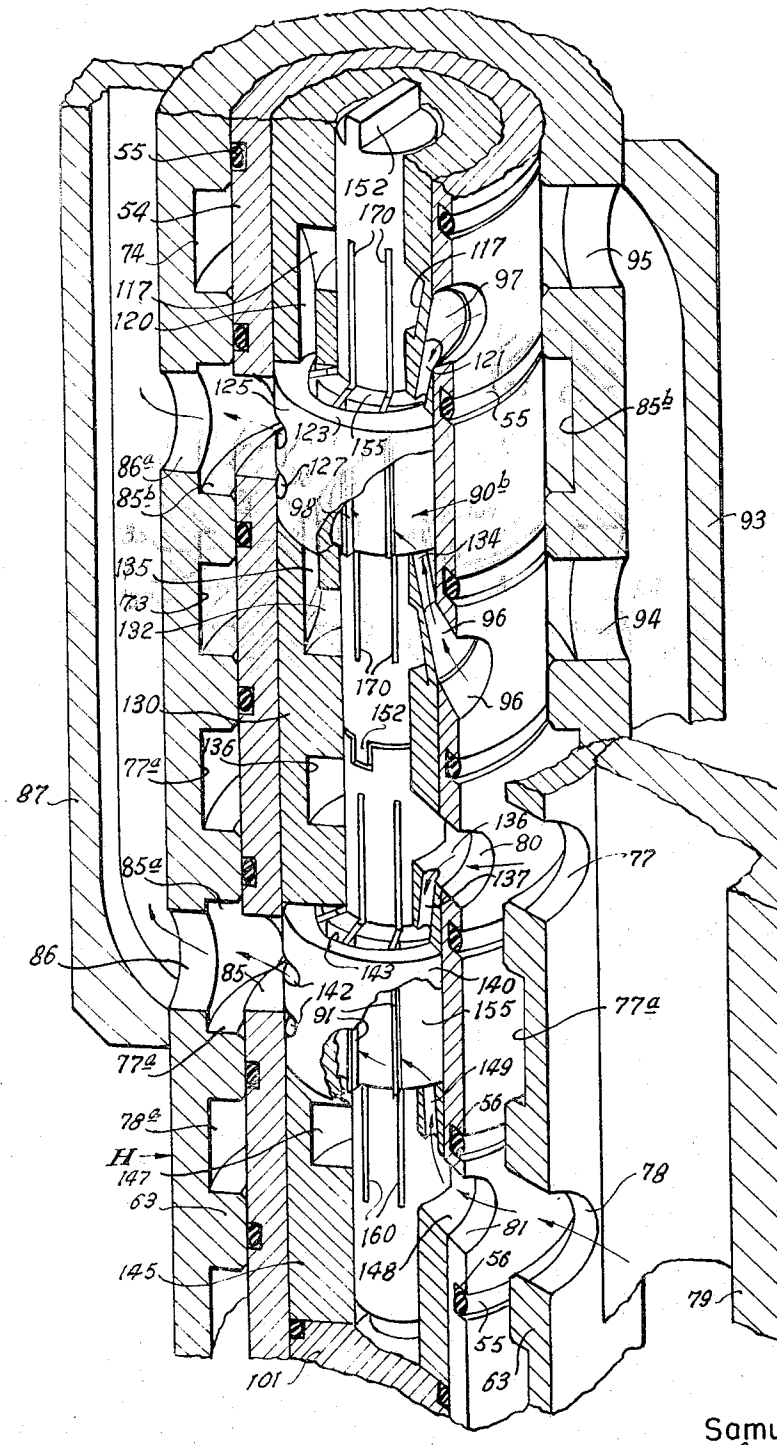


Fig. 21

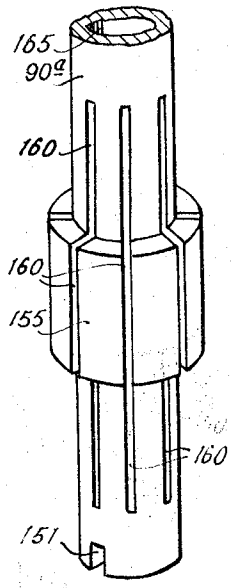


Fig. 22B

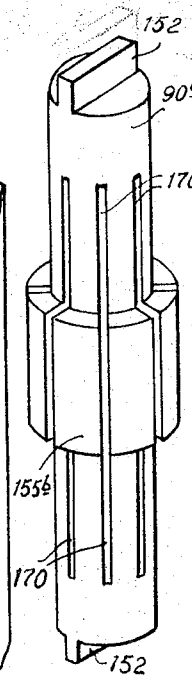


Fig. 22A

INVENTOR.
Samuel J. E. Marshall
BY Cushman, Darby & Cushman
and
Walter J. Jaeger
ATTORNEYS

Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 8

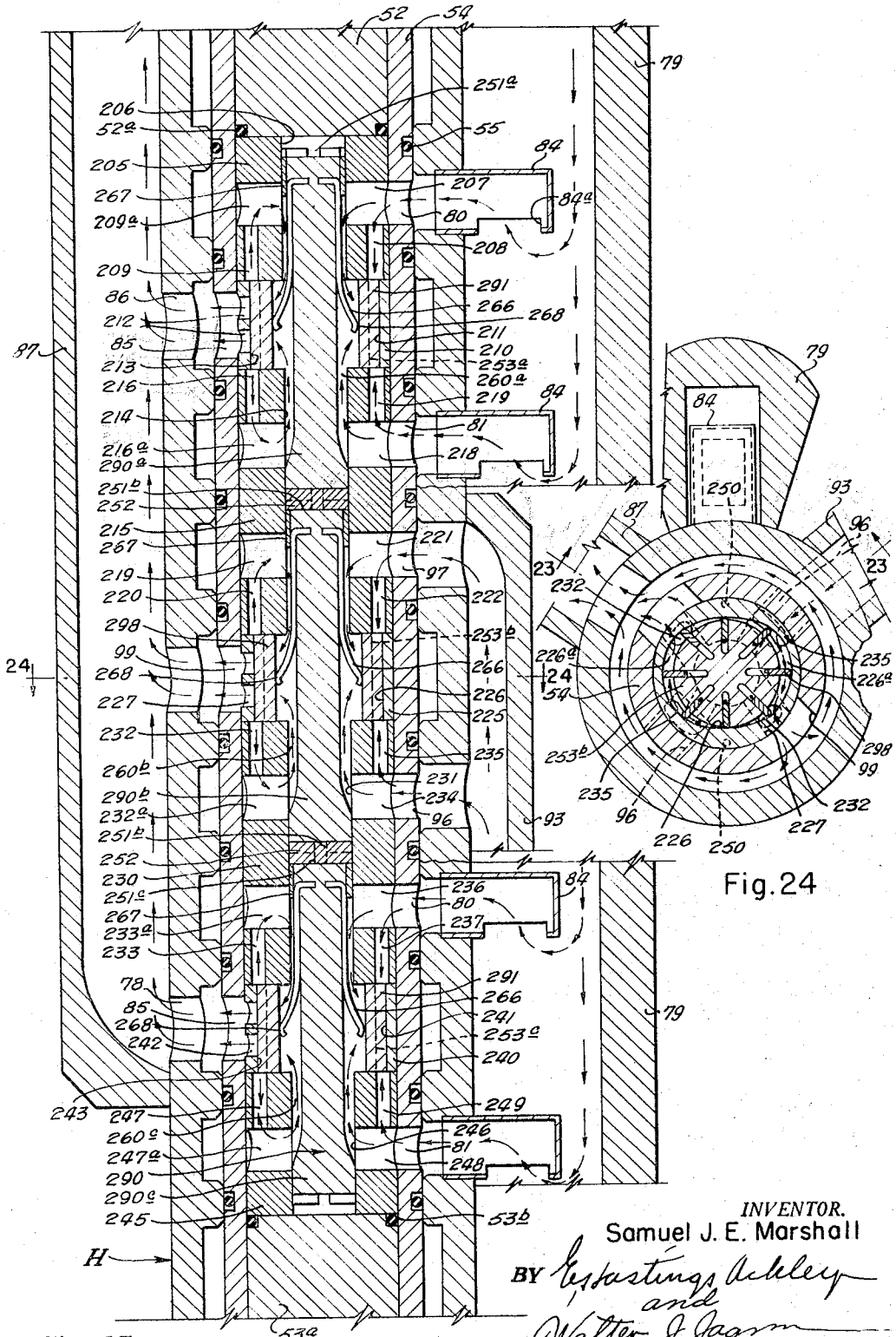


Fig. 23

Fig. 24

INVENTOR.
Samuel J. E. Marshall
BY Cushastings, Ackley and Walter J. Jagrm
ATTORNEYS

Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 9

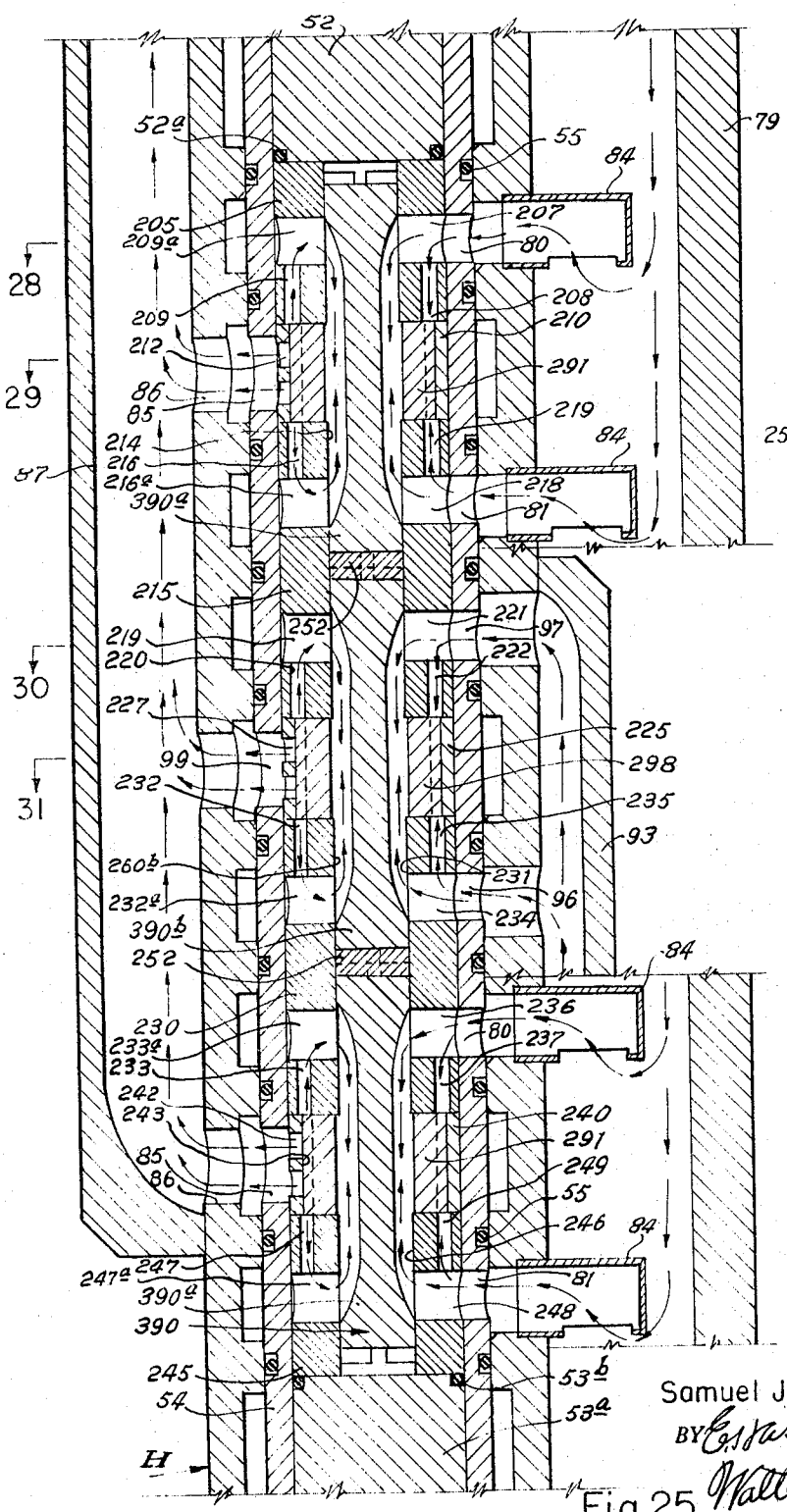


Fig.25

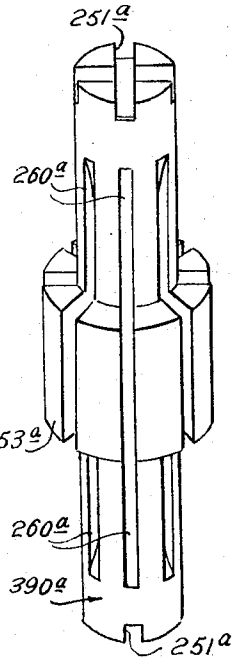


Fig.26

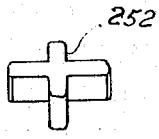


Fig.27

INVENTOR.
Samuel J. E. Marshall
BY Cushman, Darby & Cushman and Walter J. Jagger
ATTORNEYS

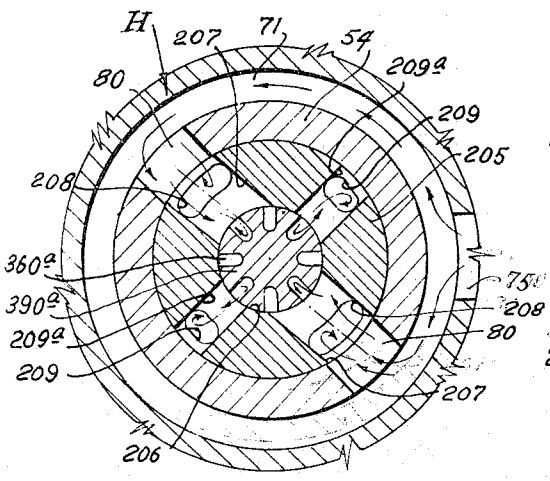


Fig. 28

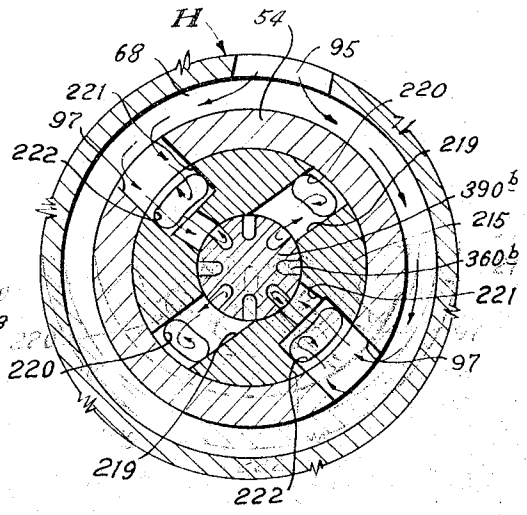


Fig. 30

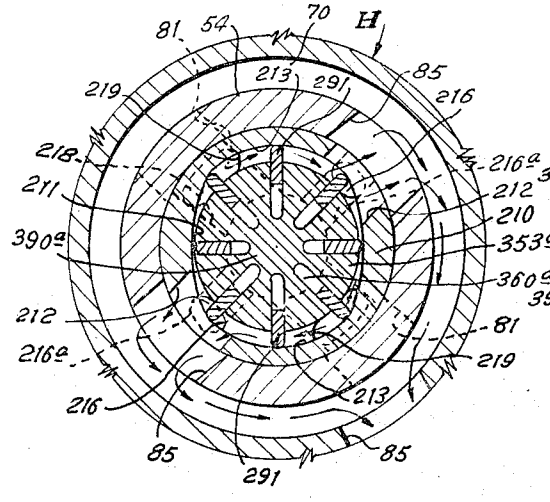


Fig. 29

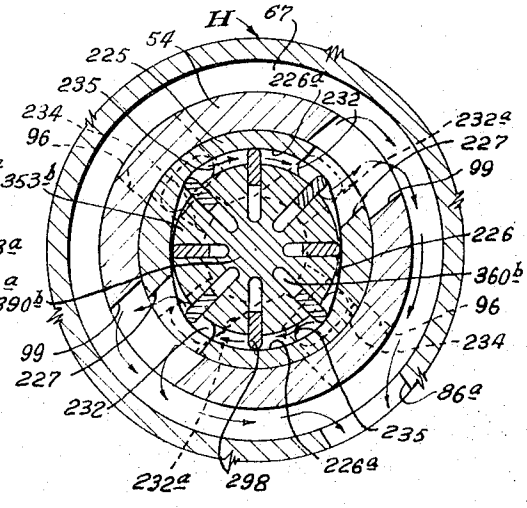


Fig. 31

INVENTOR.
Samuel J.E. Marshall
BY Cushman, Darby & Cushman
and
Walter J. Jaynes
ATTORNEYS

Jan. 24, 1967 S. J. E. MARSHALL 3,299,823

PUMPS

Original Filed Aug. 26, 1963 11 Sheets-Sheet 11

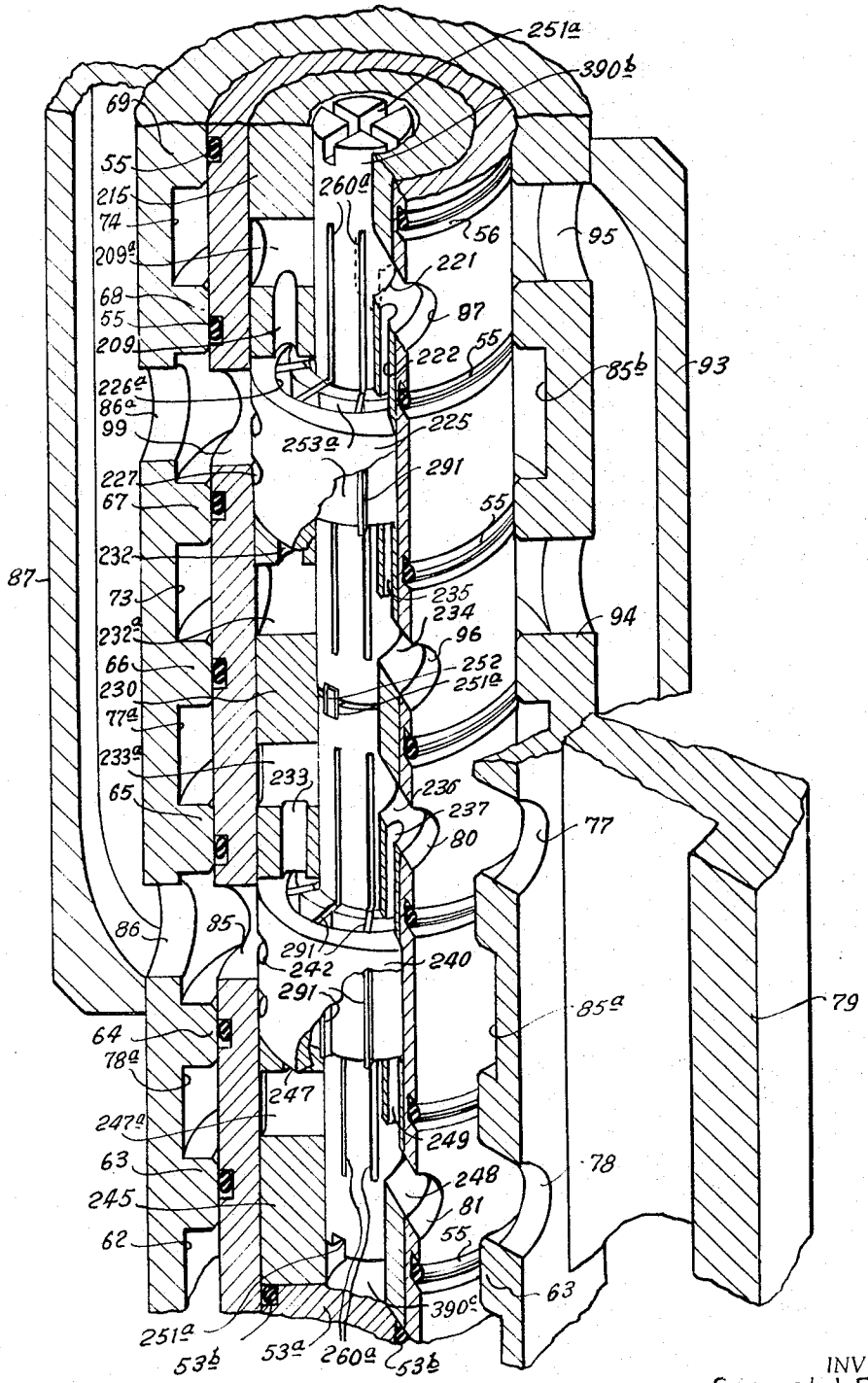


Fig.32

INVENTOR.
Samuel J.E. Marshall
BY Hastings Ackley
and
Walter J. Jagmin
ATTORNEYS

United States Patent Office 3,299,823 Patented Jan. 24, 1967

3,299,823

PUMPS

Samuel J. E. Marshall, 2218 N. Carroll St., Dallas, Tex. 75204

Continuation of application Ser. No. 304,424, Aug. 26, 1963. This application July 5, 1966, Ser. No. 564,501
15 Claims. (Cl. 103—119)

This invention relates to pumps and more particularly to fluid operated pumps. This application is a continuation of my copending application, Serial No. 304,424, filed August 26, 1963, now abandoned.

It is a particular object of the invention to provide a fluid operated rotary pump which is adapted to be mounted in a well flow conductor for the continuous recovery of the fluids from the wells and which is suitably provided with means for introducing and locating and removing the pump from the well flow conductor without removing the conductor from the well.

An important object of the invention is to provide a pump of the character described which is designed for manufacture in component sections which may be connected in multiples of motor and pumping sections whereby the capacity of the pump may be readily varied as needed and whereby any one of the motor or pump sections may be replaced without the necessity for replacinig all sections thereof.

Still another object is to provide in a fluid operated rotary pump sealing members forming a plurality of rotary fluid chambers wherein the effect of the fluid pressure of the motor fluid and fluid pressure of the pumped fluid does not cause the seal members to bind or stick as the pump is operated.

A further particular object of the invention is to provide a fluid operated rotary pump which may be driven by fluid means delivered to the motor sections of the pump from a source at a remote point for pumping fluids from a source adjacent the pump to a remote point; and, particularly for a well pump which is adapted to be mounted deep in a well for pumping fluids from the well bore by means of a power motor fluid circulated from a remote source to the well adjacent the pump and delivered into the motor sections of the pump under conditions of continuous flow, and wherein the power motor fluid may be mingled with the fluid being pumped from the well after having performed its motor driving function.

Still another object of the invention is to provide a fluid pump of the character described having a vane type pumping rotor wherein the vanes are displaced into sealing engagement with the pump cylinder or cam sleeve by resilient means and sealing pressures across the vanes are substantially equalized to reduce wear and binding of the vanes as the pump rotor is rotated.

It is also an object of the invention to provide in a pump of the character described a system for circulating the power motor fluid downwardly of the well to the motor units of the pump and wherein the inlets into the motor units of the pump are provided with trash deflectors, and wherein the mounting for the pump and the well includes a heater for heating the power fluid and thereby heating the fluid being lifted as the fluids are commingled to reduce paraffin deposits and the like; and wherein the heated power fluids heat the adjacent well formations and low viscosity crude fluids in the well to promote flow of such viscous fluids from the formations and in the well bore.

A particular object of the invention is to provide a fluid pump of the deep well type, a pumping unit which includes a housing or manifold casing adapted to be suspended on the flow conductor string of the well in

the well bore and which is provided with a receptacle for receiving the pump unit therein, and wherein the pump unit may be lowered through the flow conductor into the housing and anchored therein by means of a flexible line lowering mechanism and wherein means is provided for releasably locking the pump in place in the housing.

Still another object of the invention is to provide a pump system of the character described, means for circulating and recirculating portions of the fluid being lifted as a motor fluid for driving the pump to lift additional fluids from a well bore or the like.

Still another object of the invention is to provide in a well pumping system of the character described a plurality of check valves removably mounted in the well flow conductor at spaced elevations in the well bore below and above the pump to provide means for maintaining a column of fluid in the conductor while the pump is not in use so that upon resuming operation of the pump the well may be quickly put into production.

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

FIGURE 1 is a longitudinal vertical view, partly in elevation and partly in section, diagrammatically illustrating a well having a pump constructed in accordance with the invention installed therein;

FIG. 2 is a modified form of the installation of FIGURE 1;

FIGURE 3 is a still further modified form of installation of the pump in a well showing diagrammatically the installation and flow or movement of the fluids in the well;

FIGURE 4 is a still further modified form of the pump showing only the lower portion of the well having the pump disposed therein;

FIGURE 5 is an enlarged vertical sectional view of the lower portion of the pump of FIGURE 4 showing the heater used in connection with the pump;

FIGURES 6 and 7 are horizontal cross-sectional views taken on the lines **6—6** and **7—7** of FIGURE 5;

FIGURE 8 is a fragmentary vertical sectional view taken on line **8—8** of FIGURE 6;

FIGURE 9 is an enlarged elevation of the housing for the pump;

FIGURE 10 is a horizontal cross-sectional view taken on the line **10—10** of FIGURE 9;

FIGURE 11 is a vertical sectional view through the housing taken from the opposite side of the housing from that shown in FIGURE 9;

FIGURES 12, 13, 14 and 15 are horizontal cross-sectional views taken on the lines **12—12, 13—13, 14—14** and **15—15** of FIGURE 11;

FIGURE 16 is a side elevation of the pump unit used in the housing of FIGURE 11;

FIGURE 17 is a vertical sectional view of the upper portion of the pump unit installed in the housing;

FIGURE 18 is a continuation of FIGURE 17 showing the lower portion of the pump and housing;

FIGURES 19 and 20 are enlarged horizontal cross-sectional views taken on the lines **19—19** and **20—20** of FIGURES 17 and 18;

FIGURE 21 is an enlarged isometric view of a section of the pump in place in the housing;

FIGURE 22A is an isometric view of one of the pump rotor sections of FIGURE 21;

FIGURE 22B is an isometric view of one of the motor rotor sections of FIGURE 21;

FIGURE 23 is an enlarged vertical sectional view of a modification of the motor and pump sections of the pump assembly;

FIGURE 24 is a horizontal cross-sectional view of the housing and pump of FIGURE 23 taken on the line **24—24**;

FIGURE 25 is an enlarged vertical sectional view of another modified form of motor and pump section in place in a section of a housing;

FIGURE 26 is an isometric view of one of the rotor members of the pump assembly of FIGURE 25;

FIGURE 27 is an isometric view of a connector cross member for connecting the rotor members of the pump assembly of FIGURE 25;

FIGURES 28 and 29 are horizontal cross-sectional views taken on the lines **28—28** and **29—29** through the motor section of the pump assembly of FIGURE 25;

FIGURES 30 and 31 are horizontal cross-sectional views taken on the lines **30—30** and **31—31** through the pump section of the pump assembly of FIGURE 25;

FIGURE 32 is an enlarged isometric view of the pump assembly and housing of FIGURE 25;

FIGURE 33 is an enlarged fragmentary vertical sectional view of one of the port arrangements of the pump assembly;

FIGURE 34 is an enlarged view partly in elevation and partly in section of a check valve used in the installation of FIGURE 2; and,

FIGURE 35 is a flow diagram illustrating the manner in which a plurality of pump sections may be compounded to produce higher pressure flow.

Referring now more particularly to the drawings, FIGURES 1 through 8, a well casing C is shown disposed in a well bore in the earth extending downwardly from the surface of the earth to a producing formation. Within the casing is a flow conductor or tubing string T which extends downwardly of the casing to the level of the producing formation and below the surface of the liquid fluids present in the well. A housing H for a pump A is connected to the tubing string T to form a portion thereof and fluids entering the perforations O at the lower end of the tubing string may flow upwardly through the tubing string and the housing H to the well surface where they will pass through the usual valve connections V and flow lines L to a treater or storage tank S in the usual manner. An injection or pressure line P for power fluid extends downwardly within the casing in the annulus between the tubing T and the casing C and is connected at its lower end with the housing H as will be hereinafter more fully explained. Pressure of fluid introduced through the pressure line P into the housing H acts upon the pump A to actuate the same and to pump fluids from the well bore upwardly through the tubing T to the surface. As is shown in FIGURE 2, a plurality of check valves X may be positioned at spaced elevations in the tubing string T for the purpose of preventing back flow of fluids down the tubing string T and to maintain a staged column of fluid in the string as will be hereinafter more fully explained.

In FIGURE 3, the pump system is shown as connected at the surface by the flow lines L with a heater or treater S from which motor fluids are taken by means of a power line P*a* to a pump or compressor Y which may be powered by a suitable motor Z to inject the motor fluids downwardly through the power line or tubing P to the pump housing H for operating the pump.

In FIGURES 4 through 8 a modified form of pumping system is shown wherein a heater W is connected in the tubing string T below the perforations O for heating the fluid being pumped into the well through the power line P which is connected at its lower end with the heater W. The power fluids passing through the heater in the manner shown by the arrows in FIGURE 5 will then pass upwardly through the supplemental power line P*s* from the heater to the pump housing H for operating the pump

and pumping fluids from the well bore. The fluids injected through the pump power line P may be heated at the surface as they are pumped into the well and the heat transferred in the heater W from the power fluid to the well fluids entering the perforations O of the tubing and passing downwardly through a conductor U where they are in heat exchanging contact with the hot power fluids in the heater W and then upwardly through an inner tube R past a check or foot valve Q to the pump housing H. The details of construction of the heater and its operation also will be hereinafter more fully explained.

The exterior of the pump housing H is shown in full elevation in FIGURE 9, while a vertical cross sectional view of the housing is shown in FIGURE 10, the section being taken along the line **10—10** of FIGURE 9. A side elevational view of the pump unit A as shown in FIGURE 16, the pump unit being lowerable by wire line running tool (not shown), similar to the running tool shown in U.S. Patent No. 2,348,563, which telescopes over and engages under an external annular undercut shoulder **50** at the upper end of a fishing neck **51** on the head **52** of the pump. The running tool is used to lower the pump A downwardly through the tubing string T until the external annular flange **53** on the plug **53***a* at the lower end of the pump body **54** engages an upwardly facing internal annular stop shoulder **61** in the bore **62** of the pump housing H.

Positioned in the bore of the housing at points spaced above the stop shoulder **61** are a plurality of internal annular flanges or dividers **63** through **72**, inclusive, the inner upper and lower edges of which are beveled or chamfered to facilitate entry of the pump A therethrough. The inner annular surface of each of the flanges provides a smooth sealing surface, **63***a* through **72***a* inclusive, adapted to be engaged by a plurality of O-rings or seal rings **55** mounted in a plurality of external annular grooves **56** spaced longitudinally along the exterior of the pump body **54** at points thereon corresponding to the spacing of the flanges **63** through **72** of the housing, whereby when the pump is disposed in the housing with the flange **53** thereon engaging the stop shoulder **61** in the housing, each of the O-rings or seal rings **55** engages the internal annular sealing surface of a corresponding one of the internal annular flanges **63** through **72**, inclusive, as shown in FIGURES 16 and 17.

The pump housing H has a plurality of high pressure power fluid inlet ports **75**, **76**, **77** and **78** which are arranged in pairs, and which lead from the power fluid inlet manifold **79** through those inlet ports into the internal annular chamber **75***a*, **76***a*, **77***a*, and **78***a*, respectively, formed in the bore of the housing between the adjacent pairs of flanges or dividers disposed in the housing on opposite sides longitudinally of the respective inlet ports, whereby power fluid pumped through the power line P into the manifold **79** is directed through the ports into the chambers and to the pump assembly.

The pump A comprises a plurality of pump motor units or sections **82**, and each section has a pair of sets of two power fluid inlet ports **80** and **81** spaced longitudinally from each other and a pair of outlet ports **85** disposed medially of the section intermediate the inlet ports and circumferentially spaced from said inlet ports. An O-ring sealing ring **55** is positioned between each adjacent set of ports, and these sealing rings **55** on the exterior of the pump body seal between the body and the housing dividers or flanges on each side of each set of ports. As has been explained, the lowermost set of inlet ports **81** of the body **54** is disposed between two O-rings **55** as clearly shown in FIGURE 16. Similary, the adjacent set of outlet ports **85** is disposed between two O-rings and the upper set of inlet ports **80** of the pair of sets of inlet ports is likewise disposed between two O-rings, whereby each of the sets of the ports is fluidly separated from the other set of ports by the O-rings, each of which engages one of the dividers or flanges in the housing. Each of the pairs of sets of inlet

ports **80** and **81** with the adjacent intermediate set of outlet ports **85** is incorporated in a single pump motor unit or section **82**, and it will be understood that as many unit sections as may be desired may be incorporated in the pump and in the housing to provide for the desired volume of flow.

The pairs of sets of power fluid inlet ports **80** and **81** are provided in the pump body for receiving the power fluid from the inlet ports **75, 76, 77** and **78** of the housing. The power fluid entering through these inlet ports in the pump body actuates the pump to operate the rotor **90** therein by turning the motor vanes **91** in the pump body. The power fluid then passes through the body and outwardly through the outlet ports or discharge ports **85** formed in the body **54** of the pump and disposed between each pair of sets of inlet ports.

The fluid discharged through the outlet or discharge ports **85** is directed into a discharge chamber **85***a* or **85***c*, as the case may be, formed between the dividers **64** and **65**, and between the dividers **70** and **71**, respectively. An outlet opening or ports **86** is formed in the wall of the housing communicating with each of the outlet chambers and this outlet opening or port also communicates with the discharge manifold **87** formed on the exterior of the housing H and having at its upper end a longitudinally elongate lateral re-entry port or opening **88** communicating with the bore of the housing above the uppermost flange or divider **72**, whereby fluid discharged from the motor outlet ports **85** will pass through the discharge ports **86** of the housing and into the manifold **87**, whence it will flow upwardly in the manifold to the elongated re-entry opening **88** and into the bore of the housing and the tubing T thereabove for further flow upwardly in the tubing to the well surface.

Thus, it will be seen that the power fluid is pumped downwardly through the power line P through the intake manifold **79** thence through the inlet ports **75, 76, 77** and **78** into the housing to the pump A, whereupon the pressure fluid flows through the pump in the manner to be hereinafter more fully described and outwardly into the discharge chambers **85***a* and **85***c*, and then through the outlet or discharge openings **86** in each of said chambers to the discharge manifold **87**, whence it flows upwardly in the manifold to the re-entry port **88** and enters the bore of the housing H and flows back to the surface of the well through the tubing string T, where a portion of the fluid may be again pumped downwardly for operating the pump in a continuous cycling or circulating of the power fluid as shown by the arrows in FIGURE 3.

The well fluid to be pumped from the well, which is present in the bore of the well or in the well casing C as shown in FIGURES 1, 2 and 3, will enter through the perforations O at the lower end of the tubing string T and flow upwardly in the tubing string to the pump housing H where they will enter through the perforated strainer sleeve **57** on the lower end of the pump and pass through the strainer screen **58** confined within the sleeve. The fluids will flow upwardly in the strainer through the open upper end thereof and into a counter bore **59** in the pump plug member **53***a* into which the strainer sleeve is threaded, and will then flow outwardly from the counterbore through the lateral openings **60** in the plug into the bore of the housing. From the bore of the housing the fluids will flow through a longitudinally elongate suction opening **92** in the wall of the housing and enter the suction manifold or conduit **93** on the exterior of the housing through which they will flow upwardly to a plurality of suction inlet openings **94** and **95** opening through the wall of the housing into the suction chambers **73** and **74**, respectively, formed between the flanges or dividers **66** and **67** and between the flanges or dividers **68** and **69** in the bore of the housing.

From the suction chambers **73** and **74** the well fluid is drawn inwardly into the pump unit or section **83** of the pump assembly which is disposed between the two separate motor units or sections **82**, as shown in FIGURES 16 and 17. The well fluids flow inwardly through the inlet ports **96** and **97** of the pump section and into the bore of the housing to the pump unit impeller, where they are drawn or influenced by the pump unit impeller blades or vanes **98**, and are forced outwardly through the outlet opening **99** into the discharge chamber **85***b* from whence they will flow through the outlet opening **86***a* of the housing into the discharge manifold **87** and upwardly therein with the power fluids which have been discharged into said manifold through the outlet openings **86** from the motor units. The well fluids will then admix with the power fluids and flow upwardly in the bore of the tubing to the well surface.

It will thus be seen that the pump assembly comprises a pair of motor units **82** between which is positioned a pump unit or section **83** which is operated by the motor units for pumping the well fluids from the well bore upwardly through the tubing, the motor units of the pump assembly being actuated by the power fluid from the conduit P and power manifold **79** and acting on the motor units of the pump assembly to drive the pump unit. The commingled power and well fluids are forced upwardly in the tubing to the surface of the well by the pressure generated by the pump unit **83**.

It will be seen that the lowermost O-ring or seal ring **55** on the exterior of the pump assembly A which engages the sealing surface **63***a* on the divider **63** not only separates the well fluids which are drawn upwardly through the strainer sleeve and into the housing below the flange or divider **63** from the other fluids and directs the same outwardly through the suction outlet opening **92** in the wall of the housing to the suction manifold, but the high pressure of the power fluid which is introduced into the chamber **78***a* through the opening **78** being greater than the pressure of the well fluids being pumped will act downwardly on such lowermost O-ring to bias or hold the pump assembly downwardly against the upwardly facing stop shoulder **61** to maintain the pump assembly in place in the housing or landing nipple, counteracting and overcoming any upward force imposed on the pump assembly by the presure of the well fluids therebelow.

If desired, and it is preferable, a suitable trash deflector **84** may be positioned in each of the power fluid inlet openings **75, 76, 77** and **78** of the housing, whereby any foreign matter, sand or trash present in the power fluid pumped downwardly through the power conduit P to the power fluid inlet manifold **79** of the housing will be deflected and prevented from entering the power fluid inlet openings. Each of the trash deflectors **84** is in the form of a hollow cylindrical member closed at its outer end and open at its inner end and pressed or welded or otherwise secured in the inlet openings **75, 76, 77** and **78**. The underside of the deflector has an opening **84***a* cut therein which is covered by the body of the deflector thereabove to prevent the foreign matter from falling into the inlet opening and deflecting the same toward the bottom of the manifold. The power line P has an extension Pe at its lower end which will provide a sump or trap for any trash that may have been pumped downwardly into the housing manifold. The trash accumulating in the manifold, should it reach the level of the lowermost inlet opening **78**, may be circulated out of the manifold by removing the pump assembly A and circulating power fluid downwardly through the power line, inwardly through the inlets and back up through the tubing, or vice versa. The check or foot valve Q in the tubing string below the housing H will prevent the power fluid from entering the well formation, and the power fluid and the trash will be circulated back upwardly to the surface where it may be removed by any suitable means.

The construction and operation of the pump assembly A will now be explained in greater detail.

Within the pump body **54** and between the head **52** at the upper end of the body and the plug **53***a* at the lower

end of the body is disposed the elongate pump rotor **90**. As is shown in FIGURES 17 and 18, the rotor is formed in a plurality of sections **90***a* and **90***c*, each corresponding substantially in length to one of the motor unit sections of the pump assembly, and **90***b* corresponding to the pump unit section of the assembly. One of the motor rotor sections is shown in FIGURE 22B, and the pump rotor section in FIGURE 22A. It is preferable that a suitable disk-like spacer or washer member **100** be disposed in the pump body between the upper end of a sleeve **105** and the head **52** of the pump assembly.

The upper end of the rotor section **90***a* is embraced or surrounded by the sleeve **105** which is preferably made of a low friction material, such as brass or the like, and is silver soldered, press-fitted, shrunk-fit or otherwise suitably secured in place in the bore of the body **54** of the pump assembly. This sleeve has a longitudinal bore **106** in which the upper end of the upper rotor section is mounted and is rotatable and has intermediate its ends an internal annular groove **107** communicating with a lateral aperture **108** which is disposed in flow communication with the inlet openings **80** of the upper motor unit. A pair of downwardly and inwardly inclined flow passages **109** are formed in the lower end of the sleeve, and each passage communicates with one lobe **113** of the ovate bore **111** of the motor cylinder or cam sleeve **110**, which is likewise preferably of a wear resistant material and suitably secured in place in the bore of the body in sealing abutting engagement with the lower end of the upper sleeve **105**. The bore **111** of the motor cylinder or cam sleeve is ovate in cross-section, providing a pair of diametrically opposed lobe enlargements **113** in the bore, and the cylinder is provided with a pair of sets of outlet or discharge openings **112** in its side wall, each set of which communicates one lobe of the bore with the discharge chamber **85***c* and discharge or outlet opening **86** of the housing.

An upper or first intermediate sleeve **115**, likewise preferably formed of low friction material, is secured in the bore of the body surrounding the rotor **90** similarly to the upper sleeve **105**, and in sealing abutting engagement with the lower end of the motor cylinder or cam sleeve **110**. This intermediate sleeve has a longitudinal bore with a pair of longitudinally spaced internal annular grooves **116** and **117** formed therein which communicate with the bore of the sleeve and a pair of lateral ports **118** are formed in the upper recess and communicate with the inlet openings **81** of the upper motor unit, whereby fluid may enter therethrough into the upper annular groove **116** and the bore of the sleeve. A pair of substantially diametrically opposed upwardly and inwardly inclined inlet passages **119** communicate the upper annular groove **116** and the inlet openings **118** with the bore of the motor cylinder **110** thereabove, one passage communicating with each lobe **113** of the ovate bore of such motor cylinder. A pair of diametrically spaced downwardly and inwardly inclined lateral passages **121** communicate with the suction inlet opening **97** of the body and the annular suction inlet groove **74** of the housing or landing nipple and are inwardly inclined to communicate at their lower ends with the lobes **123** of the ovate bore **126** of a pump cylinder or cam sleeve **125** which is similar in construction to the motor cylinder **110** and which is likewise suitably secured in the bore of the body **54** of the pump assembly in abutting sealing engagement at its upper end with the lower end of the upper intermediate sleeve **115**. The bore **126** of the pump cylinder, being ovate in cross-section as is shown in FIGURE 20, is provided with a pair of sets of lateral outlet openings or discharge openings **127**, each set of which communicates one of the lobes **123** with one of the opposed sets of discharge ports **99** of the pump unit of the assembly. The lower internal annular groove **117** of the sleeve **115** has communication with the outlet or discharge openings of the pump cylinder by means of a pair of circumferentially spaced longitudinally extending passages **120**, one leading to each set of discharge openings, whereby fluids may flow from the discharge openings through the passages to the groove **117** and the bore of the sleeve **115** for acting on the pump vanes **98**, as will be hereinafter more fully described.

Below the pump cylinder or cam sleeve **125** is a second or lower intermediate sleeve **130**, which is identical in configuration to the upper intermediate sleeve **115**, but is disposed in a longitudinally reversed position with the body **54**, and secured therein by press-fit, shrink-fit, silver soldering or other suitable means, in abutting sealing engagement at its upper end with the lower end of the pump cylinder **125**. This second intermediate sleeve has a bore **131** and a pair of longitudinally spaced internal annular grooves **132** and **133** therein. A pair of diametrically opposed upwardly and inwardly inclined well fluid inlet or suction passages **134** are formed in the sleeve and each of these upwardly and inwardly inclined ports or passages **134** communicates one of the inlet openings **96** of the pump section with one of the lobes **123** in the bore **126** of the motor cylinder **125** thereabove. The upper groove **132** of the sleeve **130** has communication by means of a pair of oppositely disposed longitudinally extending passages **135** with the discharge openings **127** of the pump cylinder thereabove, whereby fluids from such discharge openings may flow through such passages and groove to the bore of the sleeve **130** for acting on the pump vanes **98**, as will be described more fully hereinafter. The lower groove **133** of the sleeve has communication by means of a pair of oppositely disposed power fluid inlet openings **136** with the upper inlet openings **80** of the lower motor unit **82** whereby power fluid may flow inwardly to said groove and downwardly and inwardly through each of a pair of diametrically opposed passages **137** to one of the lobes **143** in the ovate bore **141** of a lower motor cylinder or cam sleeve **140** which is secured in the bore of the body **54** of the pump assembly and is identical in shape to the cylinder **110** first described. The upper end of the lower motor cylinder or cam sleeve **140** sealingly abuts the lower end of the lower intermediate sleeve **130** and the lower end of such motor cylinder sealingly abuts the upper end of a lower annular sleeve **145**, the lower end of the lower sleeve abutting the lower disk-like spacer or washer member **101** and surrounding the lower end of the rotor **90**. A pair of opposed sets of lateral outlet or discharge openings **142** provide communication between the lobes **143** of the bore **141** and the discharge chamber **85***a* and with the lower discharge outlet **86** of the housing.

In the bore **146** of the lower annular sleeve **145** is formed an internal annular groove **147** which has a pair of opposed lateral openings **148** each communicating with one of the set of lower inlet openings **81** of the lower motor unit of the pump assembly. One of a pair of opposed upwardly and inwardly inclined conduits or passages **149** communicates each inlet opening **148** with one of the lobes **143** of the bore **141** of the lower motor cylinder **140** thereabove.

Each of the sleeves, the upper sleeve **105**, the upper motor cylinder or cam sleeve **110**, the first intermediate sleeve **115**, the pump or cam sleeve **125**, the second intermediate sleeve **130**, the lower motor cylinder or cam sleeve **140** and the lower sleeve **145**, is held in properly oriented position with respect to the adjacent sleeve and against rotation about its axis with respect to the other sleeves by means of dowel pins or keys **150** engaged in suitable openings formed therefor in the abutting end surfaces of the sleeves. Since all the sleeves are confined between the disk-like washers or spacer members **101** and are pressed, shrunk or otherwise secured within the body **54** in abutting sealing engagement with each other between the head **52** and the plug **53***a* of the pump assembly, it will be seen that the several sleeves form an internal sleeve or lining in the body **54**, and the aligned axial longitudinal bores of the upper sleeve **105**, the first intermediate sleeve **115**, the second intermediate sleeve

130, and the lower sleeve 145 form bearings for rotatably supporting the sections of the rotor 90 in operative position therein. Since there is a slight space between the rotor and the bore walls of the several sleeves, it will be seen that fluid may enter therebetween and will form a film which will reduce friction as the rotor is rotated in the sleeves. It will be seen also that the annular seal ring 52*a* prevents fluid leakage out of the body 54 past the head 52, and that the annular seal ring 52*b* prevents fluid leakage out of the body past the plug 53*a*.

As is shown in FIGURES 17 and 18, the rotor 90 is formed of three sections, the upper motor rotor section 90*a*, the lower motor rotor section 90*b*, and the intermediate pump rotor section 90*c*. The upper and lower motor rotor sections are identical in configuration but are disposed in longitudinally reversed position with respect to each other in the bore of the sleeves and support the intermediate pump rotor section therebetween. The inner end of each of the motor rotor sections (FIG. 22B) is provided with a transverse slot 151 in the end surface thereof which receives a transverse projecting rib or key 152 formed on each of the opposite ends of the pump rotor (FIG. 22A), whereby the rotor sections move as a unit in rotating about their longitudinal axis, so that when the motor rotor sections are turned, the pump rotor section is likewise turned.

Each of the motor rotor sections (FIG. 22B) is formed intermediate its ends with an external annular flange or cylindrical but 155 which is of substantially the same length as the length of the motor cylinder or cam sleeve, and which is of a diameter substantially equal to the minor cross-sectional axis dimension of the bore of such cylinder or cam sleeve, and this flange or cylinder hub fits in and is rotatable in the bore of such cam sleeve. The ends of the adjacent sleeve members at the opposite ends of the motor cylinder slidably confine the hubs of the rotor sections in their respective motor cylinders, the fluids flowing through the cylinder forming a friction reducing film between the hub and cylinder and sleeves. A plurality of longitudinal diametrically extending circumferentially spaced slots 160 which are curved outwardly at their ends are formed in the surface of the rotor and hub, the rotor sections shown having eight such slots. In each of the slots 160 is disposed a vane 91 for radial sliding dsplacement therein. The vanes are positioned in the slots of the rotor section and disposed within the ovate bore of the respective motor cylinders, the outward movement of the vanes being limited by the engagement of the outer edges thereof with the walls of the ovate bore of the motor cylinder in which they are disposed, and longitudinal movement of the vanes is limited by their slidable sealing engagement with the ends of the adjacent sleeve members.

The outer end of each of the motor rotor sections 90*a* and 90*c* is provided with a counterbore 165 which receives an elongate spring carrying rod or mandrel 166 having a sleeve or head 167 soldered, pressed or otherwise secured on its outer end and confining between the head and the rod or mandrel a plurality of elongate spring finger members 168 which are bowed at their inner free ends. The springs are circumferentially spaced about the mandrel, one of said spring members being disposed in each of the slots 160 of the motor rotor section. Since the springs are positioned on the exterior of the rod in longitudinally extending diametrically projecting circumferentially spaced relationship corresponding to the spacing of the slots in which the springs engage, the outwardly bowed free ends of the springs extend outwardly of the axis of the motor rotor section and engage the inner edges of each of the vanes 91 disposed in the slots of the rotor section for biasing the vanes outwardly into sealing wiping engagement with the ovate bore of the motor cylinder or cam sleeve in which the vanes are disposed. It will be noted that the spring carrying rods and sleeves may be removed easily from the rotors and replaced, should the springs wear or break, since the same are retained in place in the counterbores 165 of the motor rotor by the press-fit of the sleeve therein and by the disk-like washers 100 and 101.

The pump rotor section (FIG. 22A) is likewise formed with a plurality of longitudinal diametrically disposed circumferentially spaced slots 170, and in each of these slots is disposed a pump blade or vane 98 for radial sliding displacement. The outer edge of each vane slidably wiping, sealingly engages the ovate bore 126 of the pump cylinder or cam sleeve 125, and the ends of the vane wipe in free sliding sealing engagement the adjacent ends of the first and second intermediate sleeves 115 and 130, respectively, whereby, as the pump rotor 90*b* is turned, the vanes will wipe or sealingly engage all the surrounding walls of the chamber defined by the ovate bore wall 126 of the pump cylinder and the adjacent ends of the intermediate sleeves, and well fluid is drawn inwardly through the suction openings 94 and 95 of the housing and the suction inlet openings 96 and 97 of the body 54 of the pump unit and inwardly to the bore of the pump cylinder. As shown in FIGURE 20, the vanes will move the fluid from the two sets of opposed inlet passages 121 and 134 around the enlarged lobes 123 in the bore of the pump cylinder or cam sleeve to the opposed set of outlet openings 127, which communicate with the discharge openings 99 of the pump section and the outlet discharge opening 86*a* of the housing. The pressure of the fluids conducted from the discharge openings 127 of the pump cylinder by way of the passages 120 and 135 and the grooves 117 and 132 to the bore of the sleeves 115 and 130 enters the slots 170 of the pump rotor section 90*b* and acts on the inner longitudinal surfaces of the pump vanes 98 to bias the vanes outwardly into sealing engagement with the ovate bore 126 of the pump cylinder and maintains the vanes in such sealing engagement. Fluids will thus be moved upwardly through the conduit or manifold 87 into the bore of the tubing above the pump assembly and commingled with the power fluid and be influenced upwardly in the tubing to the surface of the well.

In the operation of the pump assembly A, power fluids from the input manifold 79 will enter through the openings 84*a* of the trash deflectors, pass through the inlet openings 75 and 76 of the housing at the upper motor unit and enter the inlet openings 80 and 81 of the upper motor unit of the pump assembly. After passing through the inlet openings 108 into the annular groove 107 of the upper sleeve 105 and entering through the openings 118 into the upper bore 116 of the first intermediate sleeve 115, the power fluids will pass downwardly through the passages 109 of the upper sleeve and upwardly through the passages 119 of the first intermediate sleeve to the entrant side of the lobes 113 in the ovate bore 111 of the motor cylinder 110, where the fluids will act on the vanes 91 in the bore of such cylinder to move the vanes toward the exit side of the lobes to force the motor rotor section 90*a* to rotate by virtue of the pressure acting on the vanes moving the same from the inlet openings 109 and 119 at the entrant side near the narrow edge of the lobes 113 toward the enlarged central portion of the lobes of the ovate bore of the motor cylinder. It will be seen that the pressure fluid will pass from the enlarged lobes 113 of the bore of the ovate cylinder into and through the discharge or outlet openings 112 of the motor cylinder as the vanes pass over such outlet openings. It will also be seen that the two pairs of inlet openings 109 and 119 into the bore of the cylinder and the two sets of outlet openings 112 from the bore of the cylinder are uniformly spaced circumferentially around the cylinder, and that the provision of eight vanes in the rotor section produces positive movement of the rotor section at all times by the power fluid, since the fluid is aways acting on at least one vane in the imperforate portion of each of the

lobes **113** of the bore of the motor cylinder between the inlet openings and the outlet openings therein.

It will also be seen that the pressure of the power fluid is permitted to pass into the slots **160** in the motor rotor section where it acts on the rear or inner edge of the vanes as well as on the outer edge and the ends thereof. Each vane is therefore pressed outwardly by the slight differential resulting from the wiping contact of the outer edge of the blade with the bore wall of the motor cylinder and by the biasing force of the bowed springs **168** pressing the vanes outwardly into wiping sealing engagement with the cylinder wall.

It will similarly be seen that the lower motor unit **82** operates in identically the same manner as the upper motor unit, fluid passing inwardly through the inlet openings **80** and **81** into the bore **141** of the motor cylinder **140** to act on the vanes **91** therein and cause the vanes to rotate. The arrangement of the inlet ports **137** and **149** and the outlet ports **142** of the motor cylinder **140** of the lower motor unit are the same as those of the uppermost unit whereby the pressure of the power fluid acting on the vanes causes the lower motor unit rotor section **90***c* to rotate in the same direction as the upper motor unit rotor section **90***a* rotates. The two motor units therefore turn the pump rotor section **90***b* in the pump unit **83**. The vanes **98** of the pump unit are not resiliently biased outwardly but are in wiping engagement with the ovate bore wall **126** of the pump cylinder **125** and, as the pump rotor section is turned, the centrifugal force exerted on the vanes or blades moves the same outwardly into engagement with the bore wall **126** of the pump cylinder. Thus, well fluid which is present in the suction conduit **93** will enter through the suction openings **94** and **95** of the housing and the suction inlet openings **96** and **97** of the pump section **83** of the body and enter the inlets **121** of the first intermediate section **115** and the inlets **134** of the second intermediate section **130** from whence they will be forced through the lobes **123** of the ovate bore **126** of the pump cylinder **125** to the outlet openings **127** to the discharge manifold **87**. It will also be seen that the pumped well fluids will likewise enter the passages **120** and **135** and the annular grooves **117** and **132** from which the fluid passes into the elongate slots **170** of the rotor section **90***b* and acts on the inner edge surfaces of the vanes **98** as well as on the sides and ends thereof. The pressure of the fluids acting on the ends of the vanes is therefore equalized, while the hydrostatic head pressure of such fluids from the discharge or outlet openings **127** supplements the centrifugal force imparted to the vanes as a result of the rotation of the rotor section and holds the vanes in sealing engagement with the ovate bore wall of the pump cylinder or cam sleeve.

The wiping sealing action of the vanes on the ovate bore wall of the pump cylinder creates a suction between the inlet openings **121** and **134** and the outlet or discharge openings **127** in the wall of said pump cylinder, whereby the well fluids are drawn inwardly through the inlet openings into the bore of the pump cylinder and forced outwardly through the discharge openings **127** of the pump cylinder and the discharge opening **99** of the pump section **83** of the body of the pump assembly, and through the discharge opening **86***a* of the housing or landing nipple to the discharge manifold **87**, whence they will flow upwardly through the re-entry port **88** of the housing into the bore of the tubing above the pump assembly and upwardly to the surface of the well. The well fluids entering the manifold **87** from the discharge opening **86***a* will commingle with the power fluid which has entered the discharge manifold through the discharge openings **86** from the motor units of the pump assembly and will flow upwardly with the power fluid to the surface.

From the foregoing, it will be seen that balanced fluid pressures are maintained on the vanes of both of the motor units **82**, and that the vanes of the pump unit **83** are maintained in sealing engagement with the bore wall of the cam sleeve of the pump unit while at the same time the fluids passing through the units lubricate the space between the cylinders or sleeves and the vanes.

It will also be seen that the slight differential applied to the vanes of the motor units does not cause the same to bind when the power fluid is introduced into the motor units to start the pump to operation. Likewise, it will be seen that the final movement of the vanes past the discharge openings in the reduced end portions of the lobes **113** of the ovate bores of the motor cylinders prevents the building up of any back pressure between the vanes and the cylinder walls, since the discharge openings extend substantially to the discharge end portion of the lobes of the bore of the cylinders corresponding in dimension to the external circumference of the rotor section rotating therein.

In operation, the housing or landing nipple H is run into the well casing C on the tubing string T with the macaroni string of power fluid tubing P strung with the tubing. After the housing has been submerged to the desired depth and the lower end of the tubing string submerged in the fluid in the bore of the well, the pump assembly A is run into the housing by means of a wire line and wire line tools (not shown), in the well known manner, for positioning in the housing or landing nipple with the external flange **53** of the pump assembly engaging the upwardly facing stop shoulder **61** of the housing, the usual foot valve or check valve Q being disposed in the tubing string below the housing or landing nipple H and the perforated section for admitting well fluids connected in the tubing string below the check valve or foot valve.

The power fluid is then pumped down from the surface through the power fluid tubing P to cause operation of the pump in the manner just described by passing through the inlet manifold **79** into the motor sections or units of the pump assembly to cause the rotor **90** to rotate and thereby rotate the pump section rotor **90***c*. As the power fluid passes through the motor sections, it is discharged into the discharge manifold **87**. The well fluids are drawn upwardly through the tubing string below the housing from the openings or apertures O in the lower end thereof past the check valve or foot valve Q into the suction manifold **93** and through the pump unit or section **83** to the discharge opening **99** from the pump section into the discharge manifold **87**, where the well fluids commingle with the power fluid and the mixed fluids flow upwardly in the manifold and inwardly through the re-entry opening **88** into the bore of the tubing above the pump and upwardly through the tubing to the surface.

If desired, the commingled fluids may be passed through the usual treater heater to a storage tank S, or a portion of such fluids may be withdrawn therefrom and recirculated through the power line or tubing P into the well for continuous cycling operation of the pump. It is preferable that the fluids should be suitably cleaned to remove foreign matter therefrom prior to re-introduction into the system through the power fluid tubing string P.

It is believed readily apparent that the number of motor units and pump units may be increased by increasing the length of the housing or landing nipple H and providing an additional number of dividers or flanges therein with suitable inlet and discharge openings and suction openings corresponding to the arrangement shown, as by positioning a second pump section or unit above the upper motor unit and another motor unit above the second pump unit, etc. Thus, the number of motor and pump units may be increased to any desired number by increasing the length of the housing H and arranging the porting and manifolding thereof to accommodate the same, and by similarly lengthening the pump assembly A to include an additional number of pump

units and motor units. However, it is desirable that motor units should be at each end of the assembly and that pump units and motor units should be alternately disposed throughout the length of the assembly.

A modified form of the installation is shown in FIGURES 4 through 8, wherein a heater assembly W is connected in the tubing string below the housing or landing nipple H. The power tubing P is connected at its lower end with an inlet coupling **180** in the upper end **181** of the elongate cylindrical heater housing **182**, and the power fluid which has been previously heated at the surface is circulated downwardly in a first chamber **183** formed in the housing **182** on one side of a pair of dividers or partitions **184** extending diametrically across the bore of the heater housing and provided at its lower end with passageways **185** permitting the heated power fluids to pass from said first chamber to the other or second chamber **186** within the heater housing. A fluid conductor U depends from the foot valve Q and is disposed axially within the housing between the dividers or partitions **184**, the partitions being welded or otherwise secured to the conductor U and to the housing to form the two chambers **183** and **186**. Inlet openings O at the upper end of the conductor U admit well fluids, which are directed downwardly within the bore of the conductor exteriorly of an elongate return tubing string R which is secured to the lower end of the check valve or foot valve Q by screw threads and extends downwardly coaxially within the bore of the conductor U to a point adjacent the lower end of the housing. The lower end of the return tube R is open whereby the well fluids entering through the openings O will be directed downwardly exteriorly of the return tubing R and in the bore of the downwardly extending conductor U in heat exchanging relationship with the hot or heated power fluid, within the heater housing **182** surrounding the downwardly extending conductor U, will then flow upwardly in the return tubing R to and through the check or foot valve Q and thence upwardly to the pump assembly landing nipple or housing H in the usual manner. This heating of the well fluids produced by the power fluid introduced through the pump reduces the viscosity of the crude well fluids being produced and the formation of paraffin deposits in the tubing and in the pump. The pressure fluid from the chamber **186** of the heater housing passes upwardly and outwardly therefrom through an outlet coupling **187** in the upper end **181** of the chamber or housing to the return or second string P*s* to the power manifold **79** of the housing, being connected to the lower end of the manifold. The upper end of the manifold to which the power string P was formerly connected in the installations of FIGURES 1 through 3 is plugged by a suitable plug **189**, whereby the power fluids will be directed from the manifold through the power fluid inlet openings into the pump assembly A in the same manner as previously described. The functioning of the pump motor units and the pump units is otherwise the same as in the forms already described. The large diameter and length of the heater assembly W also provides means for heating the well formation adjacent the heater assembly and will reduce the viscosity of the crude well fluids being pumped, and will improve the flow characteristics of both the adjacent well formation and the well fluids.

If desired, a plurality of check valves X may be disposed in the tubing string at desired elevations therein above the pump assembly to prevent back flow of well fluids and power fluids when the pump is not operating, thereby staging the liquid in the tubing and reducing the hydrostatic head of back pressure acting on the pump assembly. The check valves X, one of which is shown in FIG. 34, each include a mandrel **190** having a bore **191** therethrough and a sealing cup **192** thereon. Within the bore of the mandrel is a ball valve **193** which seats on a seat **194** formed in an enlarged portion of the bore of the mandrel. The ball is retained in the mandrel by a cross pin **195** which permits fluid to pass upwardly through the mandrel but prevents the ball from moving upwardly out of the mandrel. A plurality of outwardly and downwardly inclined supporting dogs **196** are mounted in suitable lateral apertures **197** in an upstanding sleeve **198** carried by the mandrel, and an expander wedge **199** is slidable on the reduced upper neck **200** on the mandrel and has a plurality of uniformly spaced dovetailed slots **201** in its outer downwardly tapered surface **202** receiving the correspondingly dovetailed inner end portions **203** of the dogs, and is adapted to move the dogs outwardly and inwardly as the sleeve is moved longitudinally of the mandrel neck. The check valve is run into the well with the expander member **199** in the upper position on the neck and the expander is moved downwardly on the neck to expand the dogs into a coupling recess as shown in FIGURE 34 to support the check valve at that position. A suitable fishing neck **204** on the upper end of the expander sleeve is provided for connection with a suitable running and retrieving tool (not shown) by means of which the device may be lowered into the well and removed therefrom when desired.

The wire line running and retrieving tools used for inserting and removing the check valves, and their operation, are well known and will not be further described herein, it being well understood that the check valve may be suitably lowered into the well tubing and anchored in position at a coupling recess as shown in the well known manner.

In FIGURE 23 a modified form of the motor and pump sections of the pump assembly is illustrated. The pump assembly is adapted to be mounted in the same housing as the form first described, and the head **52**, the body **54** and the plug **53***a* of the pump are identical to those of the form first described, and are given the same identifying numerals. Within the body **54** and between the head **52** and the plug **53***a* at the lower end of the body are disposed two motor sections or units with a pump unit or section therebetween, and an elongate rotor **290** consisting of a plurality of rotor sections **290***a*, **290***b* and **290***c* is rotatably mounted in said sections in substantially the same maner as that of the form first described. The upper end of the upper rotor section **290***a* is embraced or surrounded by an upper sleeve **205** which is preferably made of a low friction material and is press-fitted, shrunk fit or otherwise suitably secured in the bore of the body **54** and this upper sleeve has a longitudinal bore **206** in which the upper end of the upper rotor section **290***a* is rotatable. Immediately below the upper sleeve is a motor cylinder or cam sleeve **210**, which is likewise preferably formed of a wear resistant material and is suitably secured in place in the bore of the body **54** in sealing abutment with the lower end of the upper sleeve **205**. Below the motor cam sleeve is an upper or first intermediate sleeve **215** likewise preferably formed of low friction material and suitably secured in the bore of the body surrounding the rotor **290** with its upper end in abutting sealing engagement with the lower end of the motor cylinder or cam sleeve **210** and having its lower end in abutting sealing engagement with a pump cylinder or cam sleeve **225**. Below the pump cam sleeve is a lower or second intermediate sleeve **230** which is identical in configuration to the upper intermediate sleeve **215** but is disposed in longitudinally reversed position within the body **54**, and the upper end of this lower or second intermediate sleeve is in abutting sealing engagement with the lower end of the pump cylinder or cam sleeve and its lower end is in abutting engagement with a lower motor cylinder or cam sleeve **240**. A lower annular sleeve **245** abuts the lower end of the lower motor sleeve and is in sealing engagement therewith. Each of the sleeves, the upper sleeve **205**, the upper motor cylinder or cam sleeve **210**, the first intermediate sleeve **215**,

the pump cylinder or cam sleeve **225**, the second intermediate sleeve **230**, the lower motor cylinder or cam sleeve **240** and the lower annular sleeve **245**, is held in properly oriented position with respect to the adjacent sleeve and against rotation about its axis with respect to the other sleeves by means of dowel pins or keys **250** engaged in suitable openings formed therefor in the abutting end surfaces of the sleeves. Since all the sleeves are confined between the head **52** and the plug **53***a* of the pump assembly, it will be seen that the several sleeves form an internal sleeve or lining in the body **54** of the pump and that the aligned axial longitudinal bores of the sleeves receive and rotatably support the sections of the rotor **290** in operative position therein, as will be hereinafter more fully described.

The bore **211** of the upper motor or cylinder or camsleeve **210** is ovate in cross section, providing a pair of diametrically opposed lobe enlargements **213** in the bore thereof corresponding to the enlargements in the lobes of the bore of the motor cylinders of the first described form. The motor cylinder is likewise provided with a pair of sets of outlet or discharge openings **212** in its side wall, each set of which communicates with the discharge end of one lobe of the bore of the motor cylinder and with the discharge or outlet opening **86** of the housing. The upper motor rotor unit **290***a* has an external cylindrical enlargement intermediate its ends, and this enlarged central portion of the rotor section is disposed in the ovate bore **213** of the motor cylinder, the upper end of the cylindrical enlargement sealingly slidably engaging the lower end of the upper annular sleeve **205** and the lower downwardly facing surface of the enlargement sealingly slidably engaging the upper end of the upper intermediate sleeve **215**. The opposite ends of the rotor section **290***a* are confined in the bore of the upper annular sleeve **205** and in the upper portion of the bore of the upper intermediate sleeve **215**. The opposite ends of the motor rotor section **290***a* are provided with diametrically extending cross grooves **251***a* and a cross shaped connector or coupler **252**, such as is shown in FIGURE 27, is disposed in the grooves in the lower end of the motor rotor section **290***a* and provide a means of coupling such upper motor rotor section with the upper end of the pump rotor section **290***b* which conforms in shape and size to the motor rotor section **290***a*. The coupler **252** is engaged in the cross grooves **251***b* at the upper end of the pump rotor **290***b* and provides a means of connection between the pump rotor section and the motor rotor section whereby the two move together. The enlarged external annular flange or intermediate cylindrical hub **253***b* of the pump rotor section is disposed in the ovate bore **226** of the pump cylinder or cam sleeve **225** in sealing engagement with the smaller portions of the bore wall of such cam sleeve or cylinder and in slidable sealing engagement at its oppositely facing ends with the lower end of the upper intermediate sleeve **215** and with the upper end of the lower intermediate sleeve **230**. The lower motor rotor section **290***c* is identical in shape and configuration to the rotor section **290***a* and is coupled at its upper end to the lower end of the pump rotor section by means of the coupler **252** engaged in the crossed slots **251***b* at the lower end of the pump rotor section and in the slots **251***c* in the upper end of said lower motor rotor section. The enlarged annular flange or cylindrical hub **253***c* of the lower motor rotor section is disposed in the ovate bore **241** of the lower motor cylinder or cam sleeve **240** with the oppositely facing surfaces of the enlarged hub slidably sealing engaging the lower end of the upper cylindrical sleeve **230** and the upper end of the lower annular sleeve **245**. Since the annular flanges of the rotor sections are confined within the ovate bores of the motor cylinders and pump cylinders of the respective units in which they are mounted, it will be seen that the rotor **290** is rotatably confined within the longitudinally aligned bores of the several sleeves and is freely rotatable therein. The opposite ends of the rotor **290** adjacent the head **52** and the plug **53***a* are spaced from the head and plug because the upper and lower annular sleeves **205** and **245**, respectively, are of greater lengths than the length of the end portions of the rotor sections disposed therein.

Suitable annular sealing members **52***a* and **53***b* fluidly seal between the pump body **54** and the head **52** and the plug **53***a* of the pump assembly, whereby fluids entering the several ports of the assembly are confined within the body.

Each of the rotor sections is formed with a plurality of longitudinal diametrically extending circumferentially spaced slots **260** which are curved outwardly at their opposite ends and extend through the hub portion of the rotor section, each rotor section being shown as having eight such slots, but which may be more or less than eight. The rotor section is similar to that shown in FIGURE 26. In each of the slots **260** of the motor rotor sections is disposed a vane **291** for radial sliding displacement therein. The vanes are positioned in the slots in the hub portion of the rotor section and disposed within the ovate bore of their respective motor cylinders, the outward movement of the vanes being limited by the engagement of the outer edges thereof with the wall of the ovate bore of the motor cylinder in which they are disposed, and longitudinal movement of the vanes is limited by their slidable sealing engagement with the ends of the adjacent sleeve members. Similar vanes **298** are disposed in each of the slots **260***b* in the pump rotor section **290***b* and their outer edges slidably sealingly engage the bore wall of the pump cylinder or cam sleeve **225**, while their ends slidably sealingly engage the opposite ends of adjacent intermediate cylindrical sleeve sections **215** and **230**, respectively.

An elongate spring finger member **266** is mounted in each slot of each rotor section and has one end turned at a right angle to the elongate main body of said spring and disposed in a radially extending bore in the rotor section, and the opposite free end **268** of the spring is bowed outwardly of the slot and has a reverse bend at its extreme end. An annular sleeve **267** has a close shrunk fit, or is otherwise suitably secured as by silver soldering, on the exterior of the reduced upper end of each of the rotor sections and this sleeve surrounds, engages and confines the upper end portions of the springs in the grooves and radial apertures in the rotor section. The upper end of the shaft portion of each of the rotor sections is reduced in diameter to accommodate the sleeve, whereby the sleeve conforms in size to the external diameter of the remainder of the shaft portion of the rotor section and is rotatable therewith. Since the springs are positioned in the slots **260** of the rotor sections and their outwardly bowed free ends **268** extend outwardly of the axis of the rotor section and engage the inner edges of each of the vanes **291** disposed in the slots of the motor rotor section and the inner edge of the vanes **298** disposed in the slots of the pump section, it will be seen that the vanes are each biased outwardly into sealing wiping engagement with the ovate bore of the motor cylinders and pump cylinders in which the vanes are disposed.

Opposed lateral inlet openings **207** in the upper annular sleeve **205** communicate with the bore of the sleeve and with the grooves formed in the exterior of the upper portion of the upper motor rotor section **290***a* and power fluids entering through the openings **207** will pass inwardly therefrom to the grooves or slots in the rotor section and downwardly therein to the hub portion of the rotor section disposed in the bore of the motor cylinder or cam sleeve **210** behind the vanes **291**. In addition, longitudinally extending conduit passages **208** extend downwardly from each lateral inlet opening **207**

and communicate with the bore of the motor cylinder adjacent the inlet sides of the lobes **213** formed therein for acting on the vanes **291** to cause the rotor to be rotated about its longitudinal axis. The fluids pass around the lobes **213** of the motor cylinder forcing the vanes ahead of the fluids until the fluids enter the outlet or discharge openings **212** adjacent the opposite outlet ends of the lobes **213**. Longitudinally extending passages **209** provide communication between the fluids flowing through the outlet openings **212** and opposed lateral passages **209***a* which likewise communicate with the bore **206** of the upper sleeve **205** and with the grooves or slots in the exterior of the motor rotor section whereby fluids flowing through the outlet openings **212** are likewise conducted by way of the passages **209** and **209***a* to the inner edges or surfaces of the vanes **291**. It will thus be seen that pressures acting on the vanes on opposite edges and ends thereof are equalized at the inlet openings and at the outlet openings and that the vanes are held in wiping sealing engagement with the ovate bore wall of the motor cylinder by the springs **266** as the vanes pass the openings.

A pair of diametrically opposed inlet openings **218** are formed in the upper portion of the upper intermediate sleeve **215** for admitting power fluid from the inlet openings **81** in the walls of the pump assembly body **54**. Longitudinally extending passages **219** communicate with the inlet openings **218** and conduct fluids from the inlet openings to the inlet side of the cam lobes **213** of the motor cylinder, coacting with the fluids introduced through the passages **208** to cause rotation of the vanes and the rotor sections. Fluids from the inlet **218** will likewise pass upwardly through the slots **260** in the upper rotor section and act on the inner edges of the vanes **291**. It will thus be seen that the pressures acting on the inner and outer edges of the vanes are identical and balanced and that the pressures on the opposite ends of the vanes are likewise equal and balanced, both being the inlet pressures of the power fluid entering the lobes. The fluids will pass around the lobes through the outlet openings and will be conducted downwardly through longitudinally extending passages **216** and opposed lateral passages **216***a* into the bore of the upper portion of the sleeve **215** where the fluids will enter the grooves or slots **260** in the lower portion of the upper motor rotor and pass upwardly therein to the rear or inner edge of the vanes **291** disposed therein to balance the pressures acting on opposite edges of the vanes. It will likewise be seen that the pressures in the passages **209** and **216** are identical and that the opposite ends of the vanes are exposed to such identical pressures whereby the vanes freely float under conditions of equal fluid pressure throughout the rotation of the rotor, the vanes being held in wiping sealing engagement with the ovate bore wall of the motor cylinder by the springs **266**, as the vanes pass the openings.

The lower portion of the motor rotor section **290***a* has a rotatable sealing movement in the bore **214** of the upper intermediate sleeve **215** whereby the power fluids are confined in the bore of the sleeve thereabove.

It will also be seen that the pressure of the fluids entering into each of the motor cylinders through the inlet openings and acting on the vanes **291** to move the same around the ovate bore of the motor cylinder will remain equalized on all sides of the vanes while they are moving past such inlet openings. However, when the vanes move into the imperforate portion of the lobes between the inlet openings and the outlet or discharge openings near the opposite ends of the lobes, the pressure on the side of the vane nearest the inlet openings and the pressure acting on the ends and inner edge of the vanes will be the pressure of the motor power fluids from the inlet openings, while the pressure on the side of the vanes nearest the outlet or discharge openings will be that of the discharged power fluids present in such outlet openings; and, since the higher pressure of the fluids from the inlet openings is acting on the inner edges of the vanes, the vanes will be pressed into sealing wiping engagement with the imperforate portions of the lobes during such movement between the inlet openings and the outlet openings in the motor cylinders. While the vanes pass the outlet openings, the pressure acting on all edges and ends of the vanes is equal and the vanes may readily retract into the slots in the motor rotor section in which they are radially slidable so that they will readily pass from the lobe portions of the ovate bore of the motor cylinder into and through the reduced diameter portions of such bore between the lobes without binding or locking the rotor against rotation.

Opposed suction inlet openings **221** in the lower portion of the upper intermediate sleeve **215** communicate the suction inlet opening **97** of the housing **54** with the bore of the lower portion of said sleeve for admitting and conducting well fluids drawn upwardly to the inlet opening into the bore of the sleeve and into the slots **260***b* in the exterior of the pump rotor section **290***b*, where they will pass downwardly to the portions in the hub disposed in the bore of the pump cylinder or cam sleeve **225** and act on the inner edges of the pump vanes **298**. Longitudinally extending passages **222** communicate the inlet suction openings **221** with the inlet sides of the lobes **226***a* in the bore of the pump cylinder or cam sleeve **225**. Similar opposed inlet openings **234** in the upper portion of the lower intermediate sleeve **230** communicate with the suction inlet opening **96** in the pump body **54** and direct fluids from the inlet opening into the upper portion of the bore of such lower intermediate sleeve, where the fluids enter the longitudinal slots **260***b* in the pump rotor section **290***b* and pass upwardly in such slots into the portions of the slots formed in the hub of the rotor section disposed in the bore of the pump cylinder where they also act on the inner edges or surfaces of the pump vanes **298**. Upwardly extending diametrically opposed longitudinal passages **235** conduct fluids from the inlet openings **234** upwardly into the inlet side of the lobes **226***a* of the pump cylinder where they are drawn by the movement of the vanes in the lobes. It will thus be seen that the vanes **298** are always under fluid pressure on all sides, being biased outwardly therein to wiping sealing engagement with the ovate bore wall of the pump cylinder by the springs **266**. As the pump rotor is rotated by the motor units, the vanes pass around the ovate bore wall **226** of the pump cylinder and draw fluids inwardly through the inlet openings and force the same outwardly through a pair of diametrically opposed outlet or discharge openings **227** which communicate with the discharge openings **99** of the body **54** and with the discharge conduit **87** of the housing. A longitudinal passage **220** extends upwardly from each of the outlet or discharge openings **227** to a horizontal passage **219** which communicates with the lower portion of the bore of the upper sleeve **215** and conducts the fluids from the discharge openings into such bore where they pass downwardly by way of the slots **260***b* in the pump motor section **290***b* into the space in the hub behind the vanes **298** to equalize the fluid pressures on opposite sides of said vanes. Similarly, downwardly extending longitudinal passages **232** extend downwardly from each of the discharge openings **227** to diametrically opposed laterally inwardly extending openings **232***a* whereby the pumped well fluids from the outlet or discharge openings **227** of the pump cylinder are conducted to the upper portion of the bore of the lower intermediate cylinder, where they pass upwardly through the slots **260***b* in the pump rotor to act on the inner surfaces of the pump vanes **298** to equalize the pressures on the opposite sides thereof. It will also be seen that the pressure of the fluids from the discharge openings is conducted by way of the passages **220** and **235** to the opposite ends of the vanes **298** to equalize pressures on such opposite ends of such vanes so that the pump vanes adjacent the discharge openings are subjected on

all sides to such pressure, and the vanes float in equalized sliding sealing engagement with the bore wall of the pump cylinder.

The lower cylindrical portion of the pump rotor section **290***b* has a rotatable sealing engagement with the central portion of the bore **231** of the lower intermediate cylinder **230** whereby the pumped well fluids are confined in the bore of the cylinder thereabove and below the lower end of the upper motor rotor section **290***a*.

A pair of opposed laterally extending power fluid inlet openings **236** are formed in the lower portion of the lower intermediate cylinder **230**, and these openings communicate the power fluid inlet openings **80** in the body **54** of the pump assembly with the bore **231** of the sleeve and the grooves **260***c* in the lower motor rotor section **290***c* whereby the power fluid may flow through the grooves into the space in the hub portion of said grooves behind the motor vanes **291**. Diametrically opposed longitudinally downwardly extending flow passages **237** provide communication between the inlet passages **236** and the inlet side of the lobes **243** in the ovate bore **241** of the lower motor cylinder or cam sleeve **240** for acting on the vanes to move the same in the lobes and cause the motor rotor section **290***c* to rotate. Similarly, opposed lateral inlet openings **248** are provided in the lower annular sleeve **245** and communicate the inlet openings **81** with the lower portions of the grooves or slots **260***c* in the motor rotor section **290***c*, whereby power fluids may flow inwardly through the passages **248** to the slots and upwardly therein to the space in the hub portion behind the vanes **291** to act on the inner edges of the vanes. Likewise, a pair of diametrically opposed longitudinally upwardly extending flow passages **249** is formed in the lower annular sleeve **245** and also communicate the inlet passage **248** with the inlet side of the lobes **243** in the ovate bore of the motor cylinder for directing fluids into said lobes for acting on the vanes **291** to cause rotation of the lower motor rotor section **290***c*. It will thus be seen that the pressure of the power fluid entering through the inlets **236** and **248** is directed to both longitudinal edges and both end surfaces of the vanes **291** of the lower motor unit so that the fluid pressures on the vanes are equalized and the vanes are biased outwardly into wiping sealable slidable engagement with the ovate bore wall of the cam sleeve or motor cylinder **240** by the springs **266**. Diametrically opposed outlet or discharge openings **242** are formed adjacent the discharge side or end of each of the lobes **243** of the ovate bore of the motor cylinder **240** for discharging the power fluids which have passed through the lobes from the inlets **237** and **249** outwardly through the discharge passage **78** of the housing. Longitudinally upwardly extending passages **233** from each of the discharge openings **242** communicate with opposed radially inwardly extending passages **233***a* whereby fluids from the discharge side of the lobes of the motor cylinder may be conducted to the lower portion of the bore **231** of the lower intermediate sleeve **230** and the slots **260***c* in the lower motor rotor section **290***c*, where the fluids will be directed downwardly into the space behind the vanes **291** to equalize the fluid pressures on opposite sides of such vanes. Longitudinally downwardly extending flow passages **247** communicate between the discharge side of each of the lobes **241** and opposed inwardly extending passages **247***a* which conduct pressure fluids from the discharge side of the lobes downwardly through said passages into the bore **246** of the lower annular sleeve **245**, where the fluids will enter the slots **260***c* in the lower motor rotor section and flow upwardly therein to the space behind the vanes **291** to likewise equalize the pressures on opposite sides of the vanes. It will also be seen that the fluid pressures in the passages **233** and **247** will equalize pressures at opposite ends of the vanes whereby fluid pressures acting on the vanes are equal on all sides or edges thereof. The vanes are biased outwardly into slidable wiping sealing engagement with the ovate bore wall of the motor cylinder **240** by the spring **266** carried by the motor rotor section.

It will thus be seen that the fluid pressures acting on the vanes **291** of the motor units and the vanes **298** of the pump unit are equalized on all sides and that the vanes are held in their slidable wiping sealing engagement with the bore walls of the respective cylinder in which they move by the outwardly bowed springs **266** of each of the rotor sections **290***a*, **290***b* and **290***c*. It will also be seen that the rotor sections are held in properly spaced rotatable position in the pump assembly by the engagement of the enlarged annular mid-portions or hubs **253***a*, **253***b* and **253***c*, which are disposed within the ovate bores of the motor cylinders and pump cylinder, respectively, and that the rotor segments are connected by the couplers **252**. It will also be readily apparent that the pump assembly of this form of the invention may also be extended by increasing the length of the pump body **54** and providing suitable inlet and discharge openings therein for additional pump and motor sections, and that the pump and motor sections may be added by providing additional sleeve sections therein and rotor sections therein.

A further modified form of the motor and pump sections of the pump assembly is illustrated in FIGURES 25 to 32, inclusive. In this form of the invention, however, all of the parts of the assembly except the rotor are identical to those of the form of FIGURE 23 and are given the same identifying numerals. As is clearly shown in FIGURE 25, the rotor **390** consists of a plurality of rotor sections **390***a*, **390***b* and **390***c* which are rotatably mounted in the sleeves **205**, **210** and **215**, **225**, **230** and **240** and **245** in identically the same manner as the rotor sections **290***a*, **290***b* and **290***c* are mounted in the assembly of FIGURE 23. However, in this form of the invention, there are no springs biasing the vanes **291** and **298** of the motor sections and of the pump section outwardly. Instead, the vanes are biased outwardly only by the fluid pressure of the motor fluids entering the motor units and the pressure of the well fluids being lifted through the pump unit, and by the centrifugal force of rotation of the shafts in which the vanes are slidably mounted. It will thus be seen that power fluids from the motor unit inlets entering through the inlets **207** and **218** will pass inwardly into the bore of the upper motor cylinder and act on the vanes **291** therein to cause rotation of the upper rotor section **390***a*, and will flow outwardly through the outlet openings **86** to the discharge conduit **87**. Similarly, the power fluids will enter the openings **236** and **248** and act on the vanes **291** in the lower motor cylinder and rotate the lower rotor section **390***c* therein and will then flow outwardly through the discharge openings **78** into the discharge conduit. The rotation of the upper and lower motor rotor sections **390***a* and **390***c* will cause rotation of the pump rotor section **390***b* and the well fluids will be drawn inwardly through the suction inlet openings **221** and **234** and will be drawn through the ovate bore of the pump cylinder **225** by the vanes **298** rotating therein and discharged through the outlets or discharge openings **99** from the pump unit into the discharge conduit, all in the same manner as in the form of FIGURE 23 last described.

This construction is particularly suited to high speed gas or air operated pumps, since the centrifugal force of the rotation of the rotor will cause the vanes **291** and **298** to be biased outwardly into slidable sealing engagement with the bore walls of the motor cylinders and the pump cylinder in which they are located.

In FIGURE 33 one of the motor units of the motor sections of the pump assembly is shown provided with removable orificed inlet flow controlling members **380** and **381** for controlling the flow of gaseous or air power fluid inwardly from the inlet openings **80** and **81**, respectively, in the body of the pump assembly into the bore of the motor cylinders **210** or **240** for acting on the vanes

291 therein. Obviously, the size of the orifices 385 and 386 formed in the orifice members 380 and 381 will control the volume of gas or air admitted through the orifice into the bore of the motor cylinder of the motor unit and will therefore control the velocity of the rotation of the rotor of the assembly in which the inlet orifice members are provided.

It is readily apparent that the size of the orifices of the orifice members may be changed by removing the pump assembly from the landing nipple and by changing the orifice and reinserting the pump assembly into the landing nipple.

Thus, the speed of rotation of the pump and the volume of fluid pumped thereby may be controlled by varying the speed of rotation of the rotor by means of variations in the size of the restricted orifices in the inlet orifice members.

It is also readily apparent that the number of motor and pump units in these forms of the pump assembly may be increased in the same manner as those of the forms earlier described with the consequent increase in the volume of well fluids pumped by the pump.

In FIGURE 35 is shown diagrammatically the manner in which a plurality of motor units and pump units may be manifolded to produce a compounding of the pressure of the pumped fluids. The motor units 482 and pump units 483 are identical in construction to the motor units 82 and the pump units 83 of the various forms of the invention hereinbefore described. The pump units are mounted between adjacent motor units, there being alternatively a motor unit, a pump unit, a motor unit, and a pump unit, etc. The only change in the construction of the device is a slight change in the discharge manifolding from the pump units, in that a separate manifold for the discharge from the first pump unit and the second pump units in the assembly is provided to establish communication between the discharge ports of such pump units and the intake openings of the third pump unit. As shown in FIGURE 35, the power fluid inlet conduit manifold 479 direct power fluids from the surface or the supply of power fluid to the motor units 482 to turn the motor units. The power fluid from the motor units is discharged to the discharge manifold 487 from which it returns to the source. The pumps 483 are interconnected with the motor units 482 in the same manner as has been described and illustrated hereinbefore, and the pump units are turned by the motor units in the same manner as the units already described. The fluid to be pumped is drawn in or influenced through the suction intake conduit or manifold 493 from the source of supply of such fluid and passes into and through the first pump unit 483*a* and the second pump unit 483*b* from whence it is discharged into a discharge manifold 500 and is conducted from the first pump unit by means of said manifold 500 to the intake of the last pump unit 483*c* in the series, where the pressure is compounded, since it is introduced into the last pump unit at an elevated pressure and is delivered from such pump unit at a still greater pressure. The fluid from the last pump unit 483*c* is discharged through a discharge outlet conduit therefrom and may pass directly into the discharge conduit 487, or may alternately be directed by means of a three-way valve 501 to a separate discharge conduit 502 which would deliver the pumped fluid to the desired delivery point. If desired, of course, the valve 501 and manifold 502 may be omitted and the discharged fluids from the last pump 483*c* will be discharged into the discharged manifold 487 in the manner already described. It is believed manifest that while three pumps are shown, two of which deliver their pumped fluid through their outlets or discharge openings into the manifold 500, that the manifold may conduct the discharged pumped fluids from each pump unit with the intake of the next pump unit, or more than two pump units may be used to supply fluid to the last pump unit 483*c*. It is also believed readily apparent that if desired there may be more than one pump unit receiving the pumped fluid at an elevated pressure from a plurality of first pump units and discharging it to the outlet conduit 502. It also is believed readily apparent that the manifold 500 may be provided on the exterior of the housing H by locating the same at a radially displaced position from the other manifolds thereon, and that the discharge ports from the pumps 483*a* and 483*b* into such manifold 500 may be similarly radially displaced and communicate with such manifold, and that the intake manifold of the last pump 483*c* may likewise be radially displaced to receive the fluids from the manifold 500, while its discharge port may communicate with the discharge manifold 487 or a separate laterally offset discharge manifold 502.

It will thus be readily apparent that the arrangement of the motor pump units in this form of the pump assembly will provide for compounding or increasing the pressure of the fluid pumped by the pump assembly by merely changing the manifolding as described.

It will be seen that an improved fluid operated rotary pump has been provided which is adapted to be mounted in a well flow conductor for continuous recovery of fluids from the well and which is suitably provided with means for introducing, locating and removing the pump assembly from the well flow conductor without removing the conductor from the well. Likewise, the pump assembly is designed for manufacture in component sections which may be connected in multiples of motor and pumping unit sections whereby the capacity of the pump may be readily varied as needed and whereby any one or more of the motor or pump sections may be replaced without the necessity of replacing all sections thereof. Furthermore, the pump and motor assemblies are constructed in such a manner that the fluid pressure of the motor fluid and the pumped fluid does not cause the vanes or seal members of the pumps and motors to bind or stick as the pump assembly is operated.

It will furthermore be seen that a pump assembly has been provided wherein means for heating the fluids being pumped and the adjacent surrounding formation in wells wherein the viscosity is low and the deposition of paraffin is high to provide for increased flow of fluids from the well.

Furthermore, means is provided for maintaining a staged column of fluid in the well pipe whereby the full load of the well fluids being pumped from the well is not applied to the pump during which the pump is not operated, and whereby the column of fluid in the conductor will be quickly ejected therefrom when the pump is again put into operation.

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

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

1. A motor section for use in a fluid operated pump, comprising: a housing, a motor cylinder having an ovate axial bore disposed in said housing; cylindrical supporting sleeves in said housing at opposite ends of said motor cylinder and having reduced bores axially aligned with the bore of said motor cylinder; an elongate motor rotor section rotatably mounted in said housing and having axially aligned supporting shafts at its ends disposed in the reduced bores of said supporting sleeves and an enlarged cylindrical central hub disposed in said ovate bore of said motor cylinder; a plurality of longitudinally extending radially movable vanes disposed in circumferentially spaced longitudinally extending slots formed in said hub and said shafts of said motor rotor section, said vanes being confined in said ovate bore of said motor cylinder by said supporting sleeves and movable in sealing engagement with the ovate bore of said motor cylinder, said ovate bore providing at least a pair of lobe

enlargements in said bore which said vanes slidably sealingly engage; inlet port means for power fluid from the exterior of said motor section to one side of each lobe of said ovate bore of said motor cylinder; outlet port means from the opposite side of each of said lobes of said bore of said motor cylinder to the exterior of said motor housing; said vanes separating fluid flowing through said inlet port means to said lobes from fluid flowing through said outlet port means from said lobes of said motor section; flow passages in said supporting sleeves separately communicating the inlet port means and the outlet port means of said motor cylinder with the portions of the slots in the shafts of said rotor section for conducting fluid pressure from the inlet port means to the ends and inner edges of the vanes in said slots in said hub of said motor section and for conducting fluid pressure from the outlet port means to the ends and inner edges of the vanes in said slots for equalizing the pressures applied to the ends and inner edges of said vanes by the fluids passing through the lobes of the motor cylinder.

2. In a fluid operated pump, a pump section and a motor means for driving said pump section; said pump section comprising: a body having therein a pump cylinder having an ovate bore therein and cylindrical supporting sleeves at opposite ends of said pump cylinder and reduced cylindrical bores therein axially aligned with the ovate bore of said pump cylinder; a rotor section rotatable in said body and having axially aligned supporting shafts disposed in said bores in said sleeves and an enlarged cylindrical central hub disposed in said ovate bore of said pump cylinder, said rotor section being operatively connected at least one end to the motor drive means; a plurality of radially movable longitudinally extending vanes disposed in circumferentially spaced longitudinally extending slots formed in said shafts and said hub of said pump rotor section, said vanes being confined in said ovate bore of said pump cylinder by said supporting sleeves and slidably sealing between said hub of said rotor section and said ovate bore of said pump cylinder; inlet means communicating with one reduced portion of said ovate bore of said pump cylinder for introducing fluid to be pumped into the intermediate enlarged portion of said ovate bore of said pump cylinder to be influenced therethrough by said vanes carried by said rotor; outlet means communicating with the opposite reduced portion of said ovate bore for discharging pumped fluid from said enlarged portion of said ovate bore of said pump cylinder and housing; and means for balancing the fluid pressures acting on said vanes of said pump.

3. In a fluid operated well pump: a plurality of axially aligned rotary motor units each having a rotary pump unit disposed in axial alignment between it and the adjacent motor unit and releasably operatively connected therewith; a housing receiving said motor units and pump units and having a power fluid manifold for delivering power fluids to the motor units for operating said motor units, a discharge manifold communicating with said motor units for receiving power fluids discharged from the motor units, an inlet suction manifold from a source of fluid to be pumped communicating with the inlets of one or more of the pump units, and a discharge conduit communicating with the outlets from one or more of the pump units for conducting fluids discharged from the pump; each of said motor units comprising: a body having a bore with a motor cylinder removably secured therein and having an axial ovate bore; cylindrical supporting sleeves mounted in the bore of said body on opposite ends of said motor cylinder and having reduced bores axially aligned with the ovate bore of said motor cylinder; an elongate rotor section rotatable in said body and having cylindrical shaft end sections disposed in said bores of said supporting sleeves and an enlarged central cylindrical motor hub portion disposed in said ovate bore of said motor cylinder; a plurality of longitudinally extending circumferentially spaced separate slots formed in the periphery of said rotor section and extending from each of said shaft portions through said enlarged hub to the opposite shaft portion; a plurality of radially movable longitudinally extending vanes carried by said rotor section, one of said vanes being disposed in each of said slots and having a longitudinal dimension corresponding to that of the enlarged central hub of said rotor section, said vanes being confined in the slots in said hub portion of said rotor section by said supporting sleeves, said vanes slidably sealing between said hub portion of said rotor section and the ovate bore of said motor cylinder; said ovate bore of said motor cylinder providing at least a pair of lobe bore enlargements in said ovate bore of said motor cylinder which said vanes slidably sealingly engage; inlet port means communicating said inlet manifold of said housing with one side of each lobe of said ovate bore of said motor cylinder for conducting power fluids from said inlet manifold to said ovate bore of said motor cylinder; outlet port means communicating the discharge manifold of said housing with the opposite side of each of said lobes of said ovate motor cylinder bore for conducting fluids discharged from said ovate motor cylinder bore to said discharge manifold; said power fluid from said power fluid manifold entering through said inlet ports into one side of the lobes of the bore of said motor cylinder to act on the vanes therein to rotatably displace the vanes toward the outlet ports from the opposite end of the lobes of the bore of said motor cylinder to rotate the rotor section therewith in said body; first conduit means in said supporting sleeves communicating said inlet ports with the portions of the slots in the shaft end sections of said rotor section prior to engagement of the vane in said slot with the lobe portion of said ovate bore of said motor cylinder; second conduit means in said supporting sleeves communicating the outlet ports with said portions of said slots in said shaft end sections of said rotor section for conducting fluid from said outlet to said slots to act on said vane, said second conduits also communicating with said slot portions of said shaft sections of said rotor section during limited movement after said vane in said slot has passed out of engagement with said lobe section of said motor cylinder.

4. A fluid operated well pump of the character set forth in claim **3**, wherein each of said pump units comprises: a body having a bore with a pump cylinder removably secured therein and having an axial ovate bore; cylindrical supporting sleeves mounted in the bore of said body on opposite ends of said pump cylinder and having reduced bores axially aligned with the ovate bore of said pump cylinder; an elongate pump rotor section rotatable in said body and having cylindrical shaft end sections disposed in said bores of said supporting sleeves and an enlarged central cylindrical pump hub portion disposed in said ovate bore of said pump cylinder; a plurality of longitudinally extending circumferentially spaced separate slots formed in the periphery of said rotor section and extending from each of said shaft portions through said enlarged hub to the opposite shaft portion; a plurality of radially movable longitudinally extending vanes carried by said rotor section, one of said vanes being disposed in each of said slots and having a longitudinal dimension corresponding to that of the enlarged central hub of said pump rotor section, said vanes being confined in the slots in said hub portion of said rotor section by said supporting sleeves, said vanes slidably sealing between said hub portion of said rotor section and the ovate bore of said pump cylinder; said ovate bore of said pump cylinder providing at least a pair of lobe bore enlargements in said ovate bore of said pump cylinder which said vanes slidably sealingly engage; inlet port means communicating said inlet suction manifold of said housing with one side of each lobe of said ovate bore of said pump cylinder for conducting fluids to be pumped from said inlet suction manifold to

said ovate bore of said pump cylinder; outlet port means communicating the discharge conduit of said housing with the opposite side of each of said lobes of said ovate pump cylinder bore for conducting fluids discharged from said ovate pump cylinder bore to said discharge manifold; said fluid from said inlet suction manifold entering through said inlet ports into one side of the lobes of the bore of said pump cylinder to be influenced by the vanes therein toward the outlet ports from the opposite end of the lobes of the bore of said pump cylinder to said discharge conduit of said housing; first conduit means in said supporting sleeves communicating said inlet ports with the portions of the slots in the shaft end sections of said pump rotor section prior to engagement of the vane in said slot with the lobe portion of said ovate bore of said pump cylinder; second conduit means in said supporting sleeves communicating the outlet ports with said portions of said slots in said shaft end sections of said pump rotor section for conducting fluid from said outlet to said slots to act on said vane, said second conduits also communicating with said slot portions of said shaft sections of said pump rotor section during limited movement after said vane in said slot has passed out of engagement with said lobe section of said pump cylinder.

5. A fluid operated pump of the character set forth in claim 3 wherein: said inlet port means for conducting fluids from the power fluid manifold to said ovate bore of said motor cylinder is formed in each of said supporting sleeves and communicates with the inlet end of the lobes of said ovate bore on opposite ends of said motor cylinder; said outlet conduit from the ovate bore port means is formed in the motor cylinder wall and communicates with the outlet end of the ovate bore opposite said inlet ports; and said conduit means communicating said outlet conduit port means with said shaft end portions is formed in said supporting sleeves.

6. A fluid pump of the character set forth in claim 4, having resilient means within each of the slots in the rotor sections engaging the vane disposed in the hub portion thereof biasing said vane outwardly into sealing engagement with the ovate bore wall of the cylinder in which the vane rotates.

7. A fluid operated pump of the character set forth in claim 4, wherein: said housing has a plurality of longitudinally spaced lateral power fluid inlet ports communicating with said power manifold, a plurality of longitudinally spaced lateral fluid inlet suction ports communicating with said inlet suction manifold, and a plurality of longitudinally spaced lateral discharge ports communicating with discharge conduit; external annular sealing means is provided on said body of said pump engageable with the housing for sealing between said pump and said housing on opposite sides of each of said ports; each of said motor sections in said body of said pump assembly being separately removable from within said body, and means connecting the adjacent ends of said rotor sections of said motor units and said pump units providing for rotation of said pump units by said motor units.

8. A pump of the character set forth in claim 4, and including: an elongate eduction tubing for supporting said housing in a well bore and communicating with the discharge conduit from the housing; and back flow check valve means removably disposed in said eduction tubing at a point spaced above said pump housing for preventing back flow of fluid through said eduction tubing to said pump.

9. A pump of the character set forth in claim 4 and including: an elongate eduction tubing for supporting said housing in a well bore and communicating with the discharge conduit from the housing; and a plurality of back flow check valve means removably disposed in said eduction tubing at points spaced a predetermined distance from each other and spaced above said pump housing, for stage supporting the fluid pumped by said pump to prevent back flow of fluid through said eduction tubing below each of said check value means.

10. A pump of the character set forth in claim 3 including: a power fluid conduit for conducting power fluid from the surface of the well to the power fluid manifold of said housing; and heater means and disposed below the pump and connected with the lower end of said power fluid conduit and having conduit means for conducting power fluid from said heater means to said housing of said pump, whereby power fluids heated at the surface may be circulated downwardly through the power fluid conduit to the heater assembly for heating the fluids in the well bore and the adjacent well formation below the pump to promote flow of fluids, and said power fluids may then be conducted from the heater to the pump units for pumping the fluids from the well.

11. A pump of the character set forth in claim 10 wherein: the heater assembly comprises a cylindrical housing surrounding the lower portion of the inlet conduit below the pump housing; means dividing the heater housing into two chambers, one an inlet chamber and the other an outlet chamber, each in heat exchanging contact with the inlet conduit extending through the assembly to the pump housing; means connecting the lower end of the power fluid conduit to the inlet chamber; and means for connecting the power fluid conduit means from the outlet chamber to the power fluid manifold of the pump housing whereby the power fluids will be circulated through the two chambers of the heater housing and to the tubular pump housing in which the pump motor units are disposed for operating said pump motor units.

12. A hydraulic pump of the character set forth in claim 3 wherein: the inlet ports of said motor units are provided with removable flow controlling restrictive orifice inserts for controlling the admission of power fluid to the motor cylinder of said motor unit to control the speed of rotation of said motor rotor section by said power fluids.

13. In a fluid operated pump: a plurality of axially aligned rotary motor units each having a rotary pump unit disposed in axial alignment between it and the adjacent motor unit and operated thereby; a power fluid manifold delivering power fluids to the motor units for operating said motor units; a discharge manifold communicating with the motor units receiving power fluid discharged from the motor units; an inlet suction manifold from a source of fluid to be pumped communicating with the inlets of one or more of the pump units; a discharge conduit communicating with one or more pump units and conducting fluid discharged therefrom to the inlets of one or more of the other pump units; and a discharge conduit from such one or more of the other pump units for conducting the fluids from the pump.

14. A fluid operated well pump of the character set forth in claim 4 wherein: means is provided on said housing communicating the outlet ports of at least one of said pump units with the suction inlets of at least one other of said pump units, whereby the pressure of the fluids delivered by said at least one pump unit is increased by said at least one other pump unit as the fluids are pumped by said pump units.

15. A fluid operated well pump of the character set forth in claim 7 wherein: said tubular housing has a plurality of longitudinally spaced annular internal sealing flanges formed therein, each flange being disposed on the opposite side of one of the ports formed in said housing and providing annular chambers or flow passages in said housing between said flanges, the power fluid manifold comprises an elongate longitudinally extending external manifold member on the housing connecting the power fluid inlet ports of said housing, said inlet suction manifold comprises a longitudinally extending suction manifold on the exterior of the housing providing communication between the suction inlets of the housing and the bore of the housing below the annular sealing flanges there-

in; and the discharge conduit comprises an elongate external discharge manifold on said housing communicating the discharge ports of the housing with the bore of the housing above the uppermost internal annular flange therein, said housing having means at the opposite ends for connecting the same in a flow conductor.

References Cited by the Examiner

UNITED STATES PATENTS

1,189,085	6/1916	Fox	103—47
2,033,210	3/1936	Tennant et al.	103—44
2,308,742	1/1943	Brown et al.	103—119
2,357,334	9/1944	Kendrick et al.	91—138
2,429,043	10/1947	Barnhart	103—220
2,432,079	12/1947	Albert	103—44
2,653,551	9/1953	Rosaen	103—136
2,667,128	1/1954	Bergh	103—87
2,733,663	2/1956	Marshall	103—119

DONLEY J. STOCKING, *Primary Examiner.*

W. J. GOODLIN, *Assistant Examiner.*