Oct. 15, 1968 C. J. COBERLY 3,405,641

ROTARY, FLUID OPERATED, AXIAL PLUNGER PUMP

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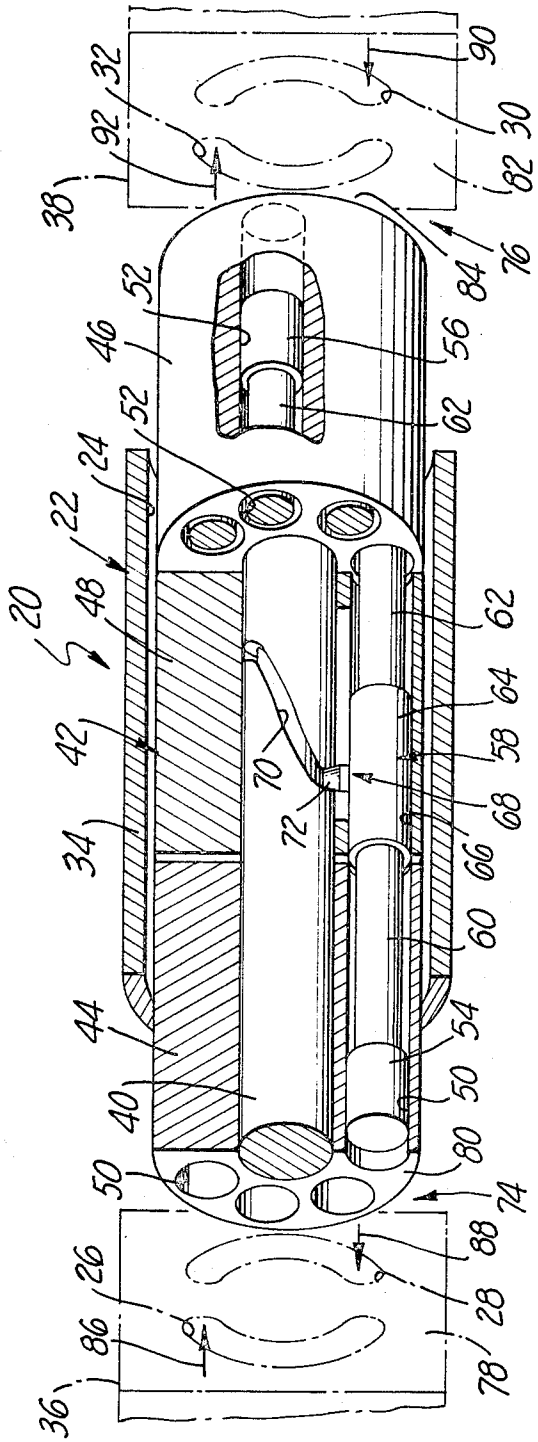


FIG. 1.

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FIG. 2a.

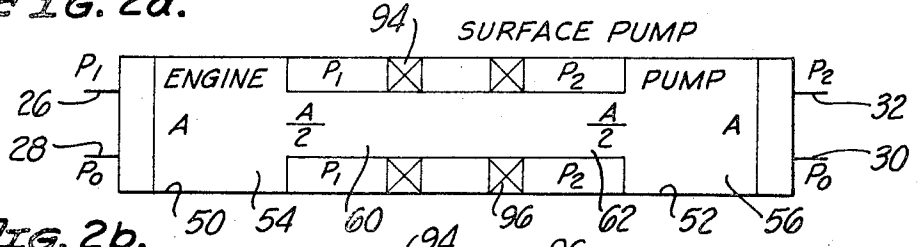


FIG. 2b.

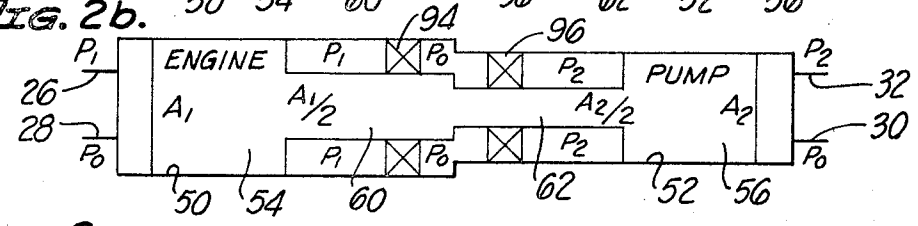


FIG. 3a.

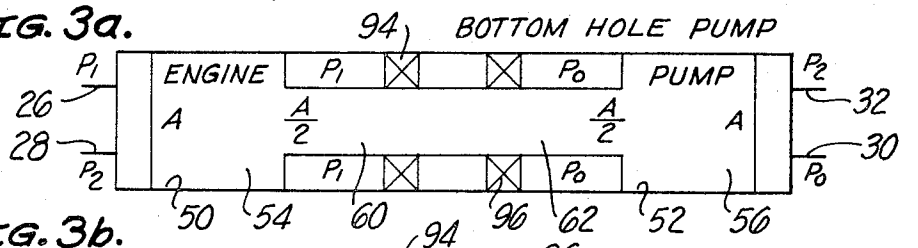


FIG. 3b.

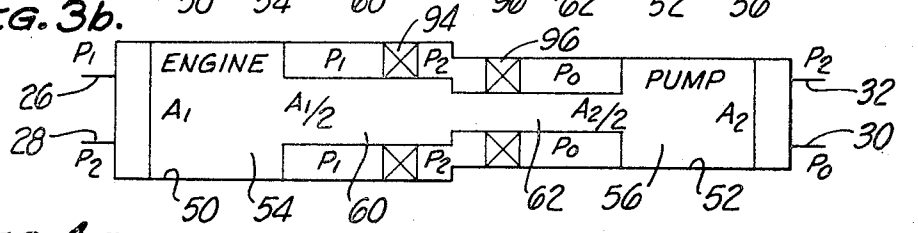


FIG. 4a.

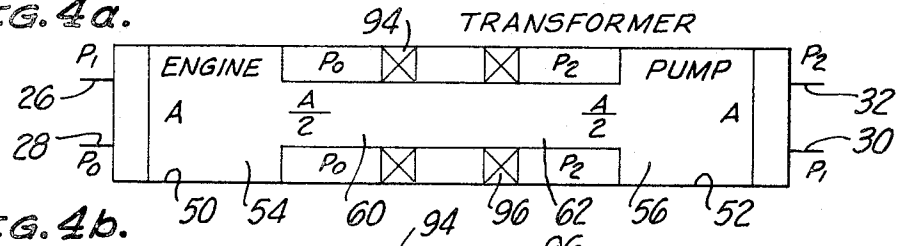
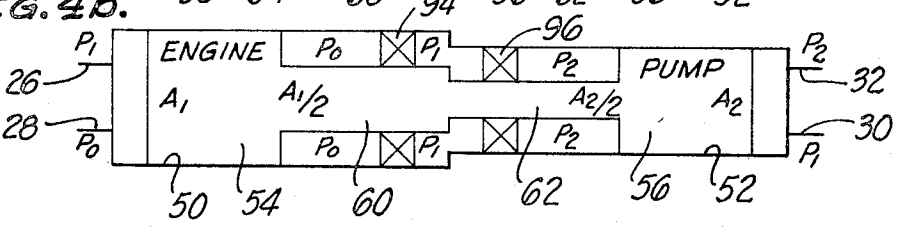


FIG. 4b.



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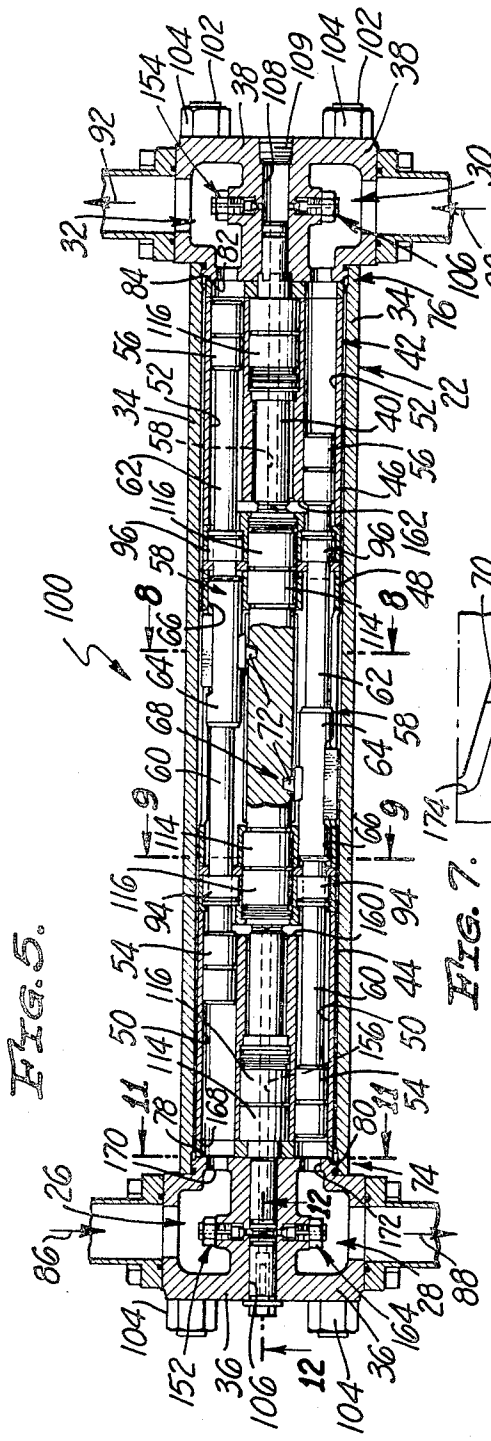


FIG. 5.

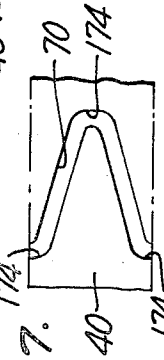


FIG. 7.

FIG. 6.

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FIG. 8.

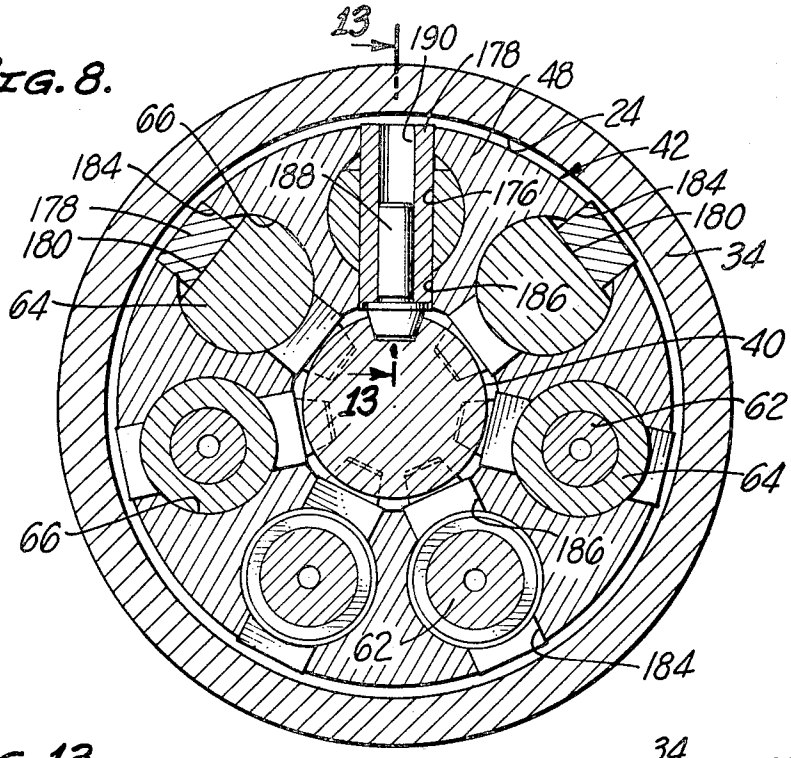
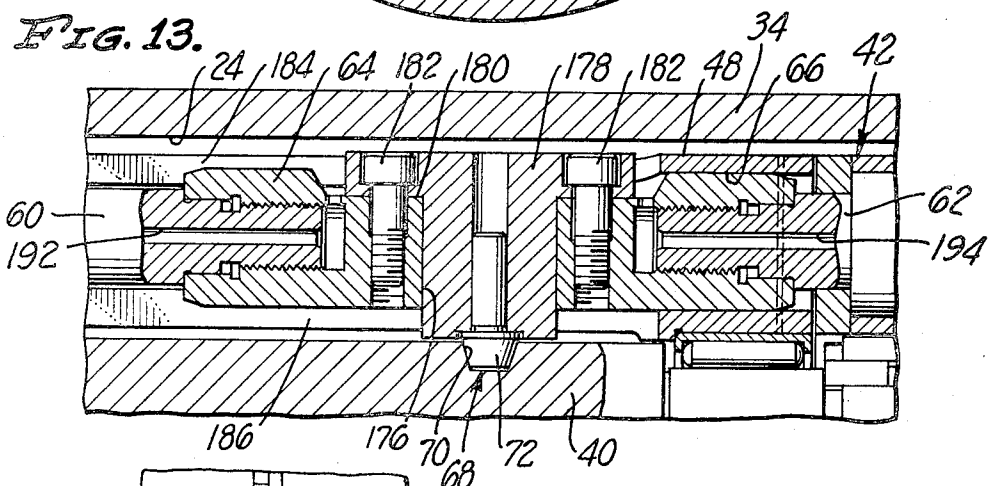


FIG. 13.



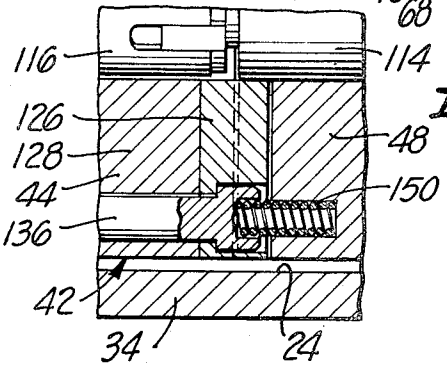


FIG. 14.

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FIG. 11.

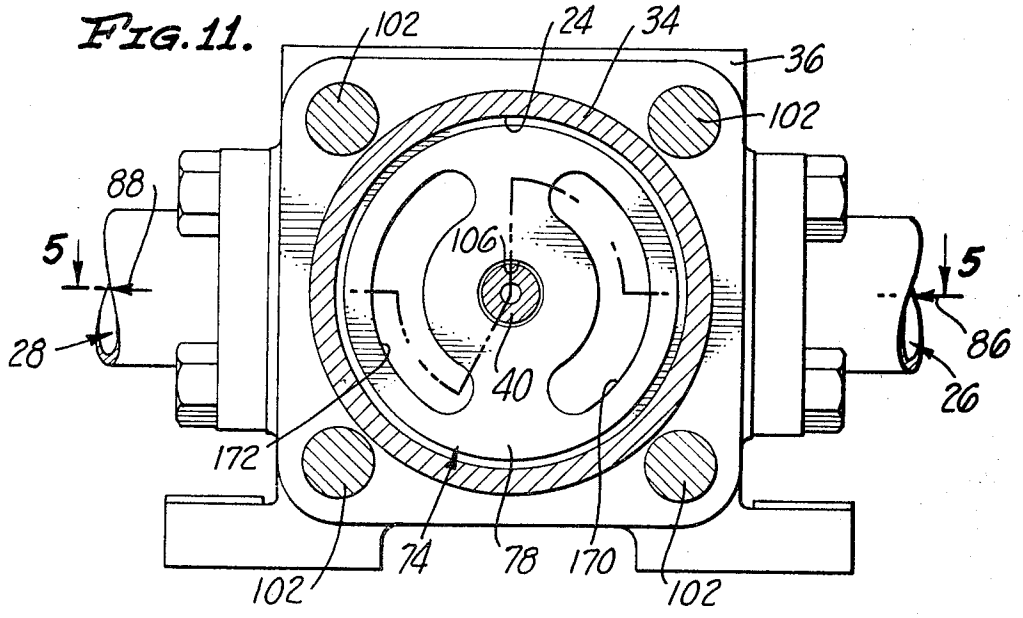


FIG. 10.

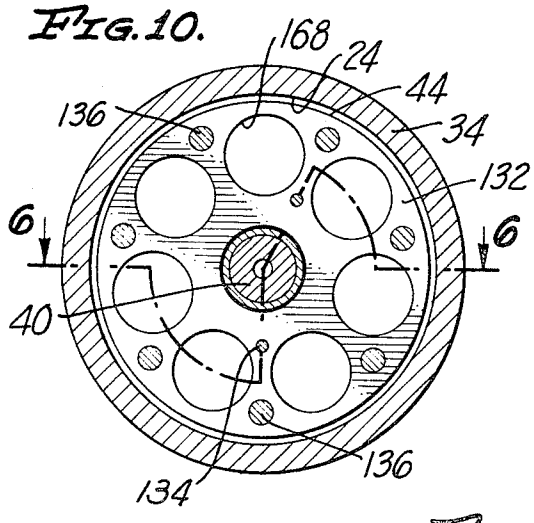


FIG. 9.

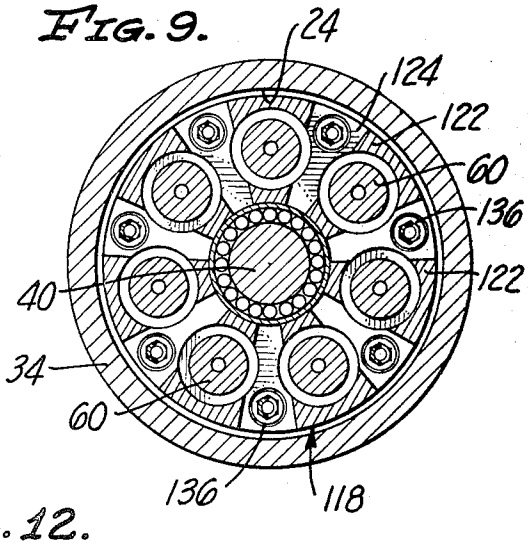
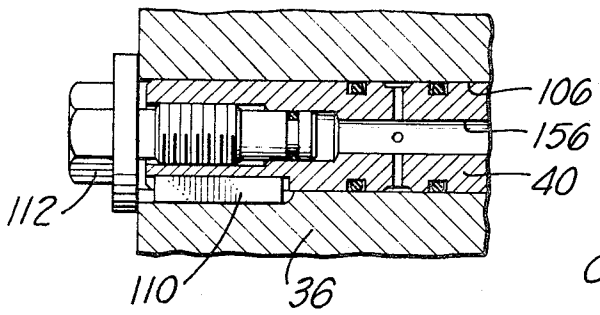


FIG. 12.



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FIG. 15.

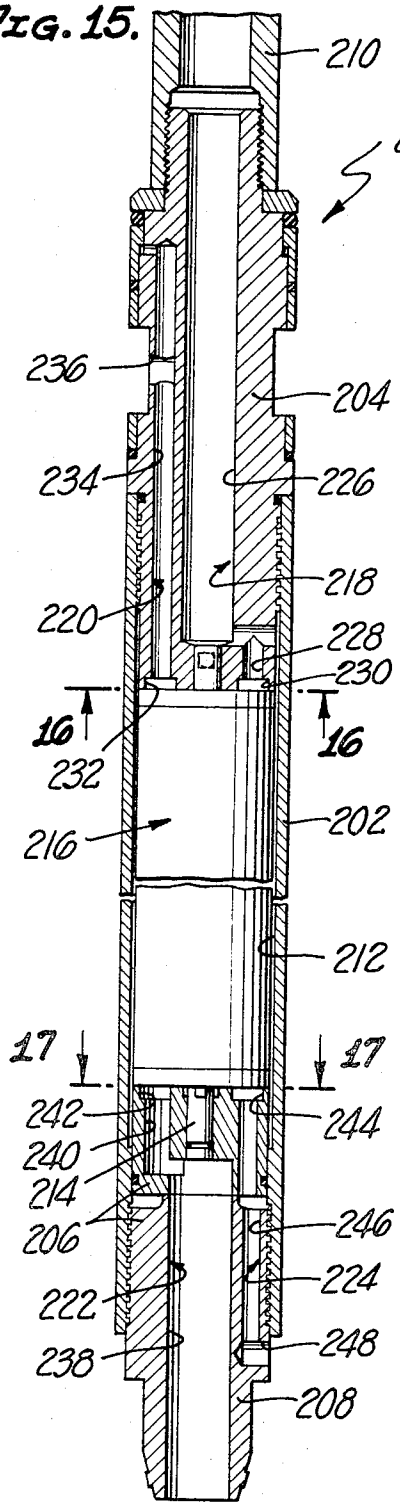


FIG. 16.

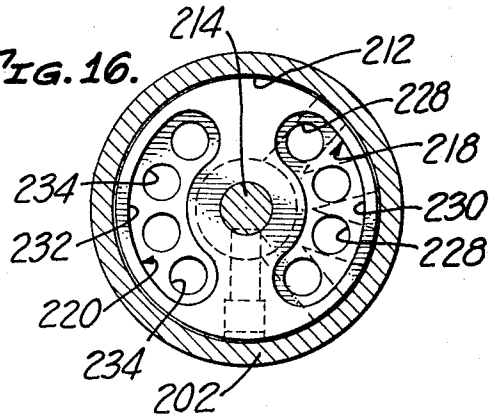
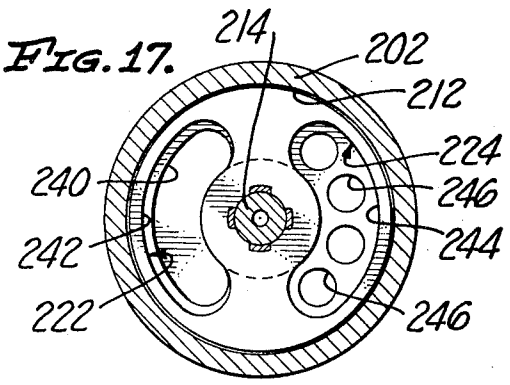


FIG. 17.



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United States Patent Office

3,405,641

Patented Oct. 15, 1968

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ROTARY, FLUID OPERATED, AXIAL PLUNGER PUMP

Clarence J. Coberly, San Marino, Calif., assignor to Kobe, Inc., Huntington Park, Calif., a corporation of California

Continuation-in-part of application Ser. No. 485,345, Sept. 7, 1965. This application May 25, 1967, Ser. No. 641,359

17 Claims. (Cl. 103—49)

ABSTRACT OF THE DISCLOSURE

A rotary, fluid operated, axial plunger pump including a housing containing a rotor on a spindle, circumferentially spaced, axial engine and pump cylinders in the respective ends of the rotor, interconnected engine and pump pistons in the respective engine and pump cylinders, engine valves responsive to rotation of the rotor for sequentially connecting the engine cylinders to an operating fluid intake and exhaust alternately, pump valves responsive to rotation of the rotor for sequentially connecting the pump cylinders to a pumped fluid inlet and outlet alternately, a cam on the spindle intermediate the ends of the rotor, and cam followers connected to the respective engine and pump piston assemblies and engaging the cam for rotating the rotor on the spindle in response to reciprocatory movement of the engine and pump piston assemblies. A sectional rotor construction comprising an engine end section carrying the engine pistons, a pump end section carrying the pump pistons and a central section guiding the cam followers and transmitting rotation to the end sections.

CROSS-REFERENCE TO RELATED APPLICATION

Ser. No. 485,345, filed by me on Sept. 7, 1965, now Patent No. 3,322,069, granted May 30, 1967, this application being a continuation-in-part.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates in general to a rotary, fluid operated, axial plunger pump comprising: a housing provided therein with a rotor chamber and having an intake and an exhaust for operating fluid and an inlet and an outlet for fluid being pumped; a spindle carried by the housing within and extending axially of the rotor chamber; a rotor in the rotor chamber and rotatably mounted on the spindle; the rotor being provided in one end thereof with circumferentially spaced, axially extending engine cylinders; the rotor being provided in the other end thereof with circumferentially spaced, axially extending pump cylinders respectively aligned with the engine cylinders; engine and pump pistons respectively reciprocable in the engine and pump cylinders; piston connecting means respectively interconnecting the engine pistons and the pump pistons; cam means on the piston connecting means and the spindle and responsive to reciprocatory movement of the interconnected engine and pump pistons for rotating the rotor about the axis of the rotor chamber; engine valve means responsive to rotation of the rotor for sequentially connecting the engine cylinders to the intake and the exhaust alternately; and pump valve means responsive to rotation of the rotor for sequentially connecting the pump cylinders to the inlet and the outlet alternately.

A rotary pump of the foregoing general nature may be used in various environments for a variety of purposes. For example, it may be used in a well, particularly an oil well, as a bottom hole pump to pump well fluid to the surface, the operating fluid and the pumped fluid being different. As another example, it may be used as a surface

pump powered by one fluid to pump the same or another fluid. As a further example, it may be utilized as a fluid-pressure transformer, either step-up or step-down, the operating and pump fluids ordinarily being the same. Still other uses may occur to those skilled in the art.

Description of the prior art

A rotary, axial plunger, fluid operated pump of the foregoing general type is disclosed in the following patent: H. E. Rose, 2,935,952, May 10, 1960. Other patents of interest are: C. R. Pratt, 1,019,521, Mar. 5, 1912; C. J. Coberly, 2,625,109, Jan. 13, 1953.

My aforementioned copending application, of which this application is a continuation-in-part, claims an improved rotary, axial plunger, fluid operated pump of the general nature outlined.

SUMMARY AND OBJECTS OF THE INVENTION

Generally speaking, the present invention contemplates a rotary, fluid operated, axial plunger pump of the general nature hereinbefore outlined which is axially short yet has a high capacity, which because of its multiple engine and pump pistons minimizes hydraulic shock in both the operating fluid and the pumped fluid, which achieves a high capacity because of its use of engine and pump pistons in axially spaced relation to achieve engine and pump areas of maximum size, which further achieves a high capacity through the utilization of large-area intake, exhaust, inlet and outlet ports formed in the end walls of the rotor and the rotor chamber, which utilizes engine and pump piston assemblies that are differential double acting to further reduce pressure pulsations, which utilizes the operating fluid under pressure to displace the engine pistons in both direction in the engine cylinders so that there is no load on the cam means other than that required to rotate the rotor to operate the engine and pump valve means, which utilizes a double acting cam means so that the motions of the engine and pump pistons can be constrained to any desired pattern, which balances the hydraulic forces on the rotor so as to give the desired contact pressures between the end walls of the rotor and the rotor chamber, and the like.

A primary object of the invention is to provide a rotary, fluid operated, axial plunger pump of the foregoing nature wherein the rotor is of sectional construction and includes an engine end section containing the engine cylinders and pistons, a pump end section containing the pump cylinders and pistons, and a central section containing and guiding cam followers connected to the respective engine and pump piston assembles and extending radially inwardly into engagement with a double acting cam carried by the spindle, such cam preferably being a peripheral groove in the spindle.

Another object is to provide two disengageable means respectively coupling the end sections of the rotor to the central section thereof in torque transmitting relation. With this construction, as the engine and piston assemblies are reciprocated by the operating fluid under pressure, the cam followers cooperate with the cam groove in the spindle to rotate the central section of the rotor about the axis of the spindle, and the central section drives the end sections of the rotor. Thus, the engine and pump piston assemblies are not required to drive any portion of the rotor so that there is no tendency to cause the engine and pump pistons to bind in their cylinders, which is an important feature.

Another object in connection with the foregoing is to provide disengageable coupling means between the central and end sections of the rotor which comprise interengageable clutch jaws on adjacent end walls of the rotor sections.

A further object is to provide means for biasing the

engine and pump end sections of the rotor axially away from the central section thereof and into engagement with the corresponding end walls of the rotor chamber, thereby insuring sealing contact between the rotor end walls and the rotor chamber end walls, which end walls form the engine valve means and the pump valve means.

Still another object is to provide a construction wherein the end walls of the rotor are formed by separate engine and pump valve plates, the engine and pump end sections of the rotor carrying circumferentially spaced, axially extending bolts respectively connecting the engine and pump valve plates thereto.

An additional object is to provide a construction wherein the housing of the pump includes a cylindrical barrel containing the rotor and includes heads secured to and closing the ends of the barrel and defining the end walls of the rotor chamber, the spindle being mounted on the two heads.

Another and important object of the invention is to provide a rotary, fluid operated, axial plunger pump wherein each of the piston connecting means respectively interconnecting the engine and pump pistons includes a coupling carrying the corresponding cam follower. A related object is to provide a construction wherein each of the piston connecting means includes piston rods extending axially from the corresponding engine and pump pistons toward and threadedly connected to the corresponding coupling.

A further object of the invention is to provide a pump of the foregoing nature wherein the couplings are substantially cylindrical and wherein the central rotor section is provided with circumferentially spaced bores having axes paralleling the axis of the rotor and slidably receiving the respective couplings therein.

Yet another object is to provide a construction wherein the cam followers are carried by cam-follower mounting elements detachably connected to the respective couplings. A related object is to provide a construction wherein the couplings are provided with slots therethrough which are oriented radially relative to the axis of the rotor chamber, the cam-follower mounting elements being disposed in the respective slots and secured to the corresponding couplings.

A further object is to provide the central rotor section with guides paralleling the axis of the rotor chamber and slidably or rollably engaged by portions of the cam-follower mounting elements.

Still another important object of the invention is to provide a rotary, fluid operated, axial plunger pump of the foregoing nature wherein the operating fluid under pressure is supplied to both the operating fluid intake and the pumped fluid inlet, whereby the pumped fluid discharged by the outlet is at a pressure higher than the pressure of the operating fluid. With this construction, the pump of the invention operates as a step-up pressure transformer.

The foregoing objects, advantages, features and results of the present invention, together with various other objects, advantages, features and results thereof which will be evident to those skilled in the art to which the invention relates, may be achieved with the exemplary embodiments of the invention illustrated in the accompanying drawings and described in detail hereinafter.

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a diagrammatic, cutaway, isometric view illustrating a rotor of a rotary, fluid operated, axial plunger pump of the general type to which the invention relates;

FIG. 2*a* illustrates diagrammatically a single engine and pump piston assembly of the rotary pump of the invention as embodied in a surface pump operable by one fluid to pump another fluid with a discharge pressure equal to the pressure of the operating fluid;

FIG. 2*b* is a view similar to FIG. 2*a*, but illustrating an embodiment capable of producing a pumped fluid discharge pressure higher than the operating fluid pressure;

FIGS. 3*a* and 3*b* are respectively similar to FIGS. 2*a* and 2*b*, but illustrate embodiments of the invention for use in a bottom-hole well pump;

FIGS. 4*a* and 4*b* are views respectively similar to FIGS. 2*a* and 2*b*, but illustrating embodiments of the invention usable as step-up pressure transformers;

FIG. 5 is a longitudinal sectional view, taken as indicated by the arrowed line **5—5** of FIG. 11, of a surface pump which embodies the invention;

FIG. 6 is another longitudinal sectional view of the pump of FIG. 5 which is taken as indicated by the irregular arrowed line **6—6** of FIG. 10;

FIG. 7 is a fragmentary developed view illustrating a cam groove formed in a spindle of the pump of FIGS. 5 and 6;

FIGS. 8 and 9 are enlarged eransverse sectional views respectively taken as indicated by the arrowed lines **8—8** and **9—9** of FIG. 5;

FIGS. 10 and 11 are enlarged transverse sectional views respectively taken as indicated by the arrowed lines **10—10** and **11—11** of FIGS. 6 and 5, respectively;

FIG. 12 is an enlarged, fragmentary, longitudinal sectional view taken as indicated by the arrowed line **12—12** of FIG. 5;

FIG. 13 is a fragmentary longitudinal sectional view taken as indicated by the arrowed line **13—13** of FIG. 8;

FIG. 14 is an enlarged, fragmentary longitudinal sectional view duplicating a portion of FIG. 6 on an enlarged scale;

FIG. 15 is a view, partially in longitudinal section and partially in elevation, of a bottom hole well pump which embodies the invention; and

FIGS. 16 and 17 are enlarged, transverse sectional views respectively taken as indicated by the arrowed lines **16—16** and **17—17** of FIG. 15.

DESCRIPTION OF THE INVENTION

General description

Fragmentarily illustrated in FIG. 1 of the drawings in a semidiagrammatic manner is a rotary, fluid operated, axial plunger pump which embodies the general principles of the invention. (For reference, this semidiagrammatic representation is designated by the numberal **20**.) The purpose of FIG. 1 is not to depict the invention in all its detail, but merely to provide a general understanding thereof. A detailed description of the invention will appear hereinafter in connection with the other figures of the drawings.

The principle-illustrating pump **20** of FIG. 1 includes a housing **22** provided therein with a cylindrical rotor chamber **24**. Formed in the housing **22** at one end of the rotor chamber **24** are an intake **26** and an exhaust **28** for the fluid used to operate the pump **20**. Similarly, the housing **22** is provided at the other end of the rotor chamber **24** with an inlet **30** and an outlet **32** for the fluid being pumped, which fluid may be the same as or different from the operating fluid.

The housing **22** is diagrammatically illustrated in FIG. 1 of the drawings as including a cylindrical barrel **34** which defines the peripheral wall of the rotor chamber **24**, and engine and pump heads **36** and **38** which are suitably connected to the ends of the barrel and define the end walls of the rotor chamber. The intake and exhaust **26** and **28** for the operating fluid are formed in the engine head **36**, while the inlet and outlet **30** and **32** for the pumped fluid are formed in the pump head **38**.

Carried by the engine and pump heads **36** and **38** and extending axially of the rotor chamber **24** is a spindle **40** on which a sectional rotor **42** is rotatably mounted. The rotor **42** includes an engine end section or engine section **44**, a pump end section or pump section **46** and an intermediate or central section **48**. The engine and pump sections **44** and **46** are disengageably coupled to the central

section 48 by torque transmitting connections which will be described hereinafter. With this construction, rotation of the central section 48 is transmitted to the engine and pump sections 44 and 46.

The engine section 44 of the rotor 42 is provided therein with circumferentially spaced engine cylinders 50 having axes paralleling the axis of the spindle 40 and the rotor 42. Similarly, the pump section 46 is provided therein with circumferentially spaced pump cylinders 52 respectively aligned with the engine cylinders 50. Respectively reciprocable in the engine cylinders 50 and the pump cylinders 52 are engine pistons 54 and pump pistons 56.

The respective engine pistons 54 and pump pistons 56 are interconnected by piston connecting means 58 which extend through the central rotor section 48. More particularly, each piston connecting means 58 includes engine and pump piston rods 60 and 62 respectively extending axially from the corresponding engine and pump pistons 54 and 56. The ends of the engine and pump piston rods 60 and 62 of the respective piston connecting means 58 are threadedly or otherwise connected to substantially cylindrical couplings 64 reciprocable in guide bores 66 in the central rotor section 48. These guide bores are aligned with the respective engine and pump cylinders 50 and 52.

The pump 20 includes cam means 68 on the couplings 64 and the spindle 40, and responsive to reciprocatory movement of the interconnected engine and pump pistons 54 and 56, for rotating the central section 48 of the rotor 42 about the axis of the rotor chamber 24, which axis coincides with the axes of the spindle 40 and the rotor 42. The aforementioned disengageable coupling means between the central rotor section 48 and the end rotor sections 44 and 46 result in transmission of rotation of the central section to the end sections. Consequently, the engine and pump pistons 54 and 56 are not themselves required to drive any portion of the rotor 42 so that there is no tendency to cause these pistons to bind in their cylinders, which is an important feature.

The cam means 68 comprises a cam 70 on the spindle 40 and cam followers 72 respectively carried by the couplings 64 and extending radially inwardly into engagement with the cam. The cam 70 is preferably a peripheral groove in the spindle 40 into which the cam followers 72 extend.

The pump 20 further includes an engine valve means 74 responsive to rotation of the rotor 42 for sequentially connecting the engine cylinders 50 to the intake 26 and the exhaust 28 alternately, and includes a pump valve means 76, also responsive to rotation of the rotor 42, for sequentially connecting the pump cylinders 52 to the inlet 30 and the outlet 32 alternately. The engine valve means is formed by the engine end walls 78 and 80 of the rotor chamber 24 and the rotor 42, respectively, while the pump valve means 76 is formed by the pump end walls 82 and 84 of the rotor chamber 24 and the rotor 42, respectively.

Considering the general operation of the pump 20, it will be apparent that as the operating fluid under pressure in the intake 26 is admitted into successive engine cylinders 50, the corresponding engine pistons 54 are displaced toward the central section 48 of the rotor 42. At the same time, the corresponding pump pistons 56 are displaced toward the pump head 38 to discharge pumped fluid from the corresponding pump cylinders 52 into the outlet 32. At the same time, successive engine and pump cylinders 50 and 52 on the opposite side of the rotor 42 communicate with the exhaust 28 and the inlet 30 as the corresponding engine and pump pistons 54 and 56 move in the opposite direction. Thus, spent operating fluid is discharged into the exhaust 28 and fluid to be pumped is drawn into the corresponding pump cylinders 52 from the inlet 30. The intake of operating fluid into the engine cylinders 50 on one side of the rotor 42 and the exhaust of spent operating fluid from the engine cylinders on the opposite side thereof are indicated by the intake and exhaust arrows 86 and 88, respectively. Similarly, the inflow of pumped fluid into the pump cylinders 52 on one side of the rotor 42 and the discharge of pumped fluid from the pump cylinders on the opposite side of the rotor are indicated by the inlet and outlet arrows 90 and 92, respectively.

As will be apparent, the cam means 68 converts the foregoing axial motions of the engine and pump pistons 54 and 56 into rotary motion of the central rotor section 48, the latter driving the end rotor sections 44 and 46. Such rotation of the engine section 44 causes the engine valve means 74 to sequentially connect the engine cylinders 50 to the intake 26 and the exhaust 28 alternately. Similarly, rotation of the pump section 46 of the rotor 42 causes the pump valve means 76 to sequentially connect the pump cylinders 52 to the inlet 30 and the outlet 32 alternately.

Diagrammatic embodiments of FIGS. 2a, 2b, 3a, 3b, 4a and 4b, generally

The basic principles of the rotary, fluid operated, axial plunger pump of the invention can be incorporated in a variety of embodiments for use in different environments and for different purposes. FIGS. 2*a*, 2*b*, 3*a*, 3*b*, 4*a*, and 4*b* respectively illustrate six such embodiments. Each of the figures mentioned shows, diagrammatically, one of the engine cylinders 50 and one of the pump cylinders 52 incorporated in the rotor 42, it being understood that the other sets are identical. The engine and pump pistons 54 and 56 reciprocable in the respective engine and pump cylinders 50 and 52 are, for convenience, shown simply as having their respective engine and pump piston rods 60 and 62 integrally interocnnected. The engine and pump piston rods 60 and 62 are shown as extending through annular seals 94 and 96, respectively. The intake 26 and the exhaust 28 for the operating fluid and the inlet 30 and the outlet 32 for the pumped fluid are shown simply as lines connected to the outer ends of the respective engine and pump cylinders 50 and 52. Each of the pressures in the intake 26, the exhaust 28, the inlet 30 and the outlet 32 is identified by the letter P plus a subscript the significance of which will be discussed hereinafter. The same is true of the pressures applied to the annular inner ends of the engine and pump pistons 54 and 56.

The various embodiments of FIGS. 2*a*, 2*b*, 3*a*, 3*b*, 4*a* and 4*b* differ in the pressures in the intakes 26, exhausts 28, inlets 30 and outlets 32 and/or in the pressures applied to the annular inner ends of the engine and pump pistons 54 and 56 and/or in the relative diameters of the engine and pump pistons 54 and 56 and the engine and pump piston rods 60 and 62. In those embodiments where the cross sectional areas of the engine and pump pistons 54 and 56 are the same, both are designated by the letter A. Where the areas are different, the engine-piston areas are designated A_1 and the pump piston areas A_2, the area A_2 being less than, and preferably one-half of, the area A_1. The areas of the engine and pump piston rods 60 and 62 are preferably one-half the areas of the corresponding engine and pump pistons 54 and 56. In the figures under consideration, the area of each piston rod 60 or 62 is thus indicated as being one-half of the area of the corresponding piston 54 or 56.

FIGS. 2*a* and 2*b* respectively disclose pumps intended for surface use and each intended to be operated by one fluid to pump the same or another fluid. FIGS. 3*a* and 3*b* respectively illustrate bottom hole pumps each actuable by a suitable operating fluid to pump well fluid. FIGS. 4*a* and 4*b* respectively illustrate step-up transformers each actuable by an operating fluid under pressure to discharge the same fluid at a higher pressure. The surface pumps of FIGS. 2*a* and 2*b*, the bottom hole pumps of FIGS. 3*a* and 3*b*, and the step-up transformers of FIGS. 4*a* and 4*b* will now be discussed in more detail under corresponding headings.

Surface pumps of FIGS. 2a and 2b

In both FIGS. 2*a* and 2*b*, the engine end of the pump is operated by the differential between an intake pressure P_1 and an exhaust pressure P_0, while the pump end of the device elevates the pressure of the same or a different fluid from an inlet pressure P_0 to an outlet pressure P_2. P_0 may, for example, be atmospheric pressure, or any other desired reference pressure. In the embodiment of FIG. 2*a*, the pump outlet pressure P_2 is the same as the engine intake pressure P_1, whereas, in the embodiment of FIG. 2*b*, the pump outlet pressure P_2 is higher than the engine intake pressure P_1 because of the differential area between the engine and pump pistons **54** and **56**.

In both of the embodiments of FIGS. 2*a* and 2*b*, the fluid pressure acting on each transverse surface of the piston assembly is designated by the letter P and the corresponding subscript. Thus, in both FIGS. 2*a* and 2*b*, the intake pressure P_1 and the outlet pressure P_2 constantly act on the inner end of the engine piston **54** and the inner end of the pump piston **56**, respectively. In addition, in FIG. 2*b*, the inlet-exhaust pressure P_0 constantly acts on the differential area between the engine and pump piston rods **60** and **62**. In each embodiment, reciprocatory movement of the piston assembly is produced by alternately applying the intake pressure P_1 and the exhaust P_0 to the outer end of the engine piston **54**, the respectively corresponding pressures acting on the outer end of the pump piston **56** being the outlet pressure P_2 and the inlet pressure P_0. The piston assembly in each instance moves to the right, as viewed in FIGS. 2*a* and 2*b*, when the intake pressure P_1 is applied to the outer end of the engine piston **54**. When the exhaust pressure P_0 is applied thereto, the intake pressure P_1 constantly acting on the annular inner end of the engine piston **54** causes the piston assembly to move to the left. Thus, it will be apparent that the piston assembly is powered in both directions. This is important because the cam means **68** is required only to rotate the rotor **42**, and is not required to produce any piston-assembly movement in either direction. Thus, the load on the cam means **68** is minimized, which is an important feature.

It should also be pointed out in connection with both FIGS. 2*a* and 2*b* that the pumping devices illustrated are differential double acting. This is important because it minimizes pressure pulsations.

Bottom hole pumps of FIGS. 3a and 3b

The bottom hole pumps of these figures are respectively generally similar to the surface pumps of FIGS. 2*a* and 2*b*. The pressures acting on the various transverse surfaces are all indicated in FIGS. 3*a* and 3*b* so that detailed discussions will not be necessary, except to point out that the exhaust pressures P_2 acting on the engine pistons **54** and the outlet pressures P_2 acting on the pump pistons **56** are all column pressures corresponding to the heads of fluid above the pumps in the wells in which they are installed. It will be noted that both embodiments are differential double acting and that that piston assemblies are both powered in both directions to minimize the loads on the cam means for rotating the corresponding rotors.

Step-up transformers of FIGS. 4a and 4b

The transformer of FIG. 4*a* corresponds to the surface pump and the bottom hole pump of FIGS. 2*a* and 3*a*, respectively, while the transformer of FIG. 4*b* corresponds to the surface pump and the bottom hole pump of FIGS. 2*b* and 3*b*, respectively. The alternating and constant pressures applied to the various transverse areas of the piston assemblies are all shown in FIGS. 4*a* and 4*b* and require no detailed discussion, except to point out certain important differences.

One important difference is that in both FIGS. 4*a* and 4*b*, the pump inlet pressure is the same as the engine intake or operating fluid pressure P_1. Consequently, the pump outlet pressure P_2 is a stepped-up pressure higher than the engine operating fluid pressure P_1. In the case of the equal-area pistons of FIG. 4*a*, the pump outlet pressure P_2 is twice the engine operating fluid pressure P_1. In FIG. 4*b*, the pump outlet pressure P_2 is even higher. Thus, these devices act as fluid pressure transformers which are actuated by an operating fluid under pressure to discharge the same fluid at a pressure higher than the operating fluid pressure.

It will also be noted that in both FIGS. 4*a* and 4*b*, the piston assembly is powered in both directions. More particularly, each piston assembly is powered toward the right as viewed in these figures, by the operating fluid pressure P_1 acting on the outer end of the engine piston **54**. When the pressure P_0 is applied to the outer end of the engine piston **54**, the piston assembly is powered to the left because of the fact that the operating fluid pressure P_1 is simultaneously applied to the outer end of the pump piston **56**. Thus, in each instance, the only load on the corresponding cam means **68** is that required to rotate the corresponding rotor **42**.

Either of the step-up transformers of FIGS. 4*a* and 4*b* may be used wherever a relatively low operating fluid pressure P_1 is available and it is desired to provide a higher fluid pressure P_2 for some purpose. Merely as an example, assume that a number of fluid operated, bottom hole, oil well pumps (similar, perhaps, to the bottom hole pumps of FIGS. 3*a* and 3*b*) are to be supplied with operating fluid at different pressures to meet different pumping requirements. Such a system may include a single primary fluid pressure source, such as a multistage centrifugal pump, having a large volumetric output at a relatively low pressure. The fluid discharged by such a single primary source can be used to operate a number of the step-up transformers of FIGS. 4*a* and/or 4*b*, such transformers in turn supplying the bottom hole pumps in the wells. For example, one such transformer may double the pressure supplied by the primary source and deliver it to one or more bottom hole pumps requiring such a doubled pressure. Another transformer may triple the fluid pressure of the primary source and deliver it to one or more bottom hole pumps requiring an operating fluid pressure of this magnitude. As will be apparent, this general concept may be extended to any desired number of transformers in bottom hole pumps, all drawing their basic hydraulic power supply from one or more primary sources. Of course, the same principles may be applied to other fluid operated systems.

When the devices of FIGS. 4*a* and 4*b* are utilized as step-up transformers in the manner hereinbefore described, it will be understood that they require a relatively large volume of fluid at the operating fluid pressure P_1 to produce a relatively smaller volume of higher-pressure fluid at the pressure P_2. However, these devices may also be utilized, if necessary, as step-down transformers by utilizing the pump end as the engine end and vice versa. In this case, a relatively small volume of fluid at the pressure P_2 will produce a relatively larger volume of fluid at the lower pressure P_1. Thus, such transformers may be utilized both as step-up and step-down pressure transformers in any system requiring pressures both above and below the pressure available from the primary source.

Surface pump of FIGS. 5 to 14

These figures illustrate a surface pump **100** which incorporates the basic principles of the pump **20** of FIG. 1 and the surface pump of FIG. 2*a*. Consequently, this section of the present specification will largely be restricted to describing structural features of the surface pump **100** which have not already been described in conjunction with FIGS. 1 and 2*a*.

Referring initially to FIGS. 5 and 6 of the drawings, the engine and pump heads **36** and **38** abut the corresponding ends of the cylindrical barrel **34** and have axially short portions telescoped into such ends. The

barrel 34 and the engine and pump heads 36 and 38 are held in assembled relation, to form the housing of the pump 100, by circumferentially spaced bolts 102 located externally of the barrel and extending through the heads. Nuts 104 threaded on the ends of the bolts 102 clamp the barrel 34 between the heads 36 and 38. (For clarity, the portions of the bolts 102 between the heads 36 and 38 have been omitted from FIGS. 5 and 6.)

For convenience of manufacture, the engine and pump heads 36 and 38 are identical and interchangeable. The engine head 36 has an axial bore 106 therethrough and the pump head 38 has an axial bore 108 therethrough which is closed by a plug 109 at its outer end. It will be noted that the intake 26 and the exhaust 28 in the engine head 36 involve symmetrical porting, the same being true of the inlet 30 and the outlet 32 in the pump head 38. With this construction, the intake 26 and the exhaust 28 are reversible, the same being true of the inlet 30 and the outlet 32.

One end of the spindle 40 is disposed in the axial bore 106 in the engine head 36 and the other end thereof extends into the axial bore 108 in the pump head 38. Referring to FIG. 12, the spindle 40 is held against rotation by a key 110 in matching keyways in the engine head 36 and in the spindle end which is disposed in the axial bore 106. The spindle 40 is held against axial movement by a bolt 112 threaded into the spindle end within the axial bore 106. The bolt 112 is seated against the outer end of the engine head 36 and serves to seat an annular stop on the spindle 40 against the inner end of the engine head, as shown in FIGS. 5 and 6.

The rotor 42 is mounted on the spindle 40 by means of bearings 114, there being a bearing 114 for the engine section 44 adjacent the engine head 36, two bearings 114 for the central section 48 adjacent the respective ends thereof, and a bearing 114 for the pump section 46 adjacent the pump head 38. Axially inwardly of the bearings 114 for the engine and pump sections 44 and 46 are seals 116 between such sections and the spindle 40. Additional seals 116 between the spindle 40 and the engine and pump sections 44 and 46 are located axially outwardly of the bearings 114 for the central rotor section 48. Each of the seals 116 is of the type having a part held stationary relative to the spindle 40 and a part rotatable with the corresponding rotor section.

The central rotor section 48 is disengageably coupled, or, more accurately, disengageably keyed, to the respective engine and pump sections 44 and 46 by dog or jaw clutches 118 and 120 so as to transmit cam-induced rotation of the central rotor section 48 to the engine and pump sections 44 and 46. As best shown in FIG. 9, the clutch 118 includes circumferentially spaced, radial jaws or dogs 122 on the corresponding end of the central rotor section 48, and includes complementary, circumferentially spaced, radial jaws or dogs 124 on the adjacent end of the engine section 44. The construction of the clutch 120 is the same as that of the clutch 118. With this construction, the various rotor sections can be assembled and disassembled easily and, when assembled, are locked together in torque transmitting relation.

The central rotor section 48 is shown as formed in a single piece. In the particular construction illustrated, the engine section 44 includes a clutch plate 126 forming part of the clutch 118, a seal housing 128 for one of the seals 116 and for the engine-piston-rod seals 94, a cylinder member 130 in which the engine cylinders 50 are formed, and an engine valve plate 132 which forms part of the engine valve means 74 and which forms the engine valve end wall 80. Dowels 134 angularly position the valve plate 132 relative to the cylinder member 130. The various parts of the enginer rotor section 44, viz., the clutch plate 126, the seal housing 128, the cylinder member 130 and the engine valve plate 132, are held in assembled relation by bolts 136 which have heads seated in recesses in the clutch plate 126 and which extend through the seal housing 128 and the cylinder member 130 into threaded engagement with the engine valve plate 132. It will be noted that the cylinder member 130 houses one of the bearings 114 and one of the seals 116 and that the engine valve plate 132 holds these elements in place. With this construction, the various components associated with and forming the engine rotor section 44 are easily assembled and held in assembled relation.

The pump rotor section 46 has a similar construction. More particularly, it includes a clutch plate 138 forming part of the clutch 120, a seal housing 140 containing one of the seals 116 and the pump-piston-rod seals 96, a cylinder member 142 in which the pump cylinders 52 are formed, a pump valve plate 144 forming part of the pump valve means 76 and providing the pump valve end wall 84 of the rotor 42, dowels 146 for angularly positioning the pump valve plate 144 relative to the cylinder member 142, and bolts 148 for securing the various parts of the pump section together.

As shown in FIGS. 6 and 14, the end walls of the central rotor section 48 are provided therein with spring cavities which contain compression coil springs 150. These springs are seated in spring cavities in the heads of the bolts 136 and 148 for securing the various parts of the engine and pump sections 44 and 46 together. As will be apparent, the springs 150 bias the engine and pump sections 44 and 46 axially away from the central section 48 to urge the engine and pump valve end walls 80 and 84 of the rotor 42 into engagement with the respective engine and pump valve end walls 78 and 82 of the rotor chamber 24. Thus, the springs 150 help to insure fluidtight engagements between the respective rotor end walls and rotor-chamber end walls constituting the engine and pump valve means 74 and 76. The sealing engagements provided by the springs 150 may be supplemented by fluid pressure acting on the inner ends of engine and pump sections 44 and 46.

As shown in FIG. 2*a* of the drawings, the operating fluid pressure P_1 and the pumped fluid discharge pressure P_2 are constantly applied to the annular inner ends of the engine and pump pistons 54 and 56, respectively. Considering how this is accomplished in FIG. 5, the intake 26 containing operating fluid at the pressure P_1 and the outlet 32 containing pumped fluid at the pressure P_2 respectively contain valves 152 and 154 carried by the respective engine and pump heads 36 and 38 and adapted to admit fluid at the pressures P_1 and P_2 into the respective axial bores 106 and 108. Communicating with the valves 152 and 154 are axial passages 156 and 158 in the spindle 40. The passages 156 and 158 extend axially to chambers 160 and 162 respectively formed in the engine and pump sections 44 and 46 between the respective seal housings 128 and 140 and the respective cylinder members 130 and 142 thereof. The chambers 160 and 162 respectively communicate with the inner ends of the engine and pump cylinders 50 and 52, and thus apply the intake and outlet pressures P_1 and P_2 to the annular inner ends of the respective engine and pump pistons 54 and 56.

(The exhaust 28 and the inlet 30 contain valves 164 and 166 respectively similar to the valves 152 and 154 and adapted to connect the exhaust 28 and the inlet 30 to the passages 156 and 158 leading to the respective chambers 160 and 162. To obtain P_1 and P_2 at the inner ends of the engine and pump pistons 54 and 56, as shown in FIG. 2*a*, the valves 152 and 154 are open and the valves 164 and 166 are closed, the same being true of the mode of operation shown in FIG. 2*b*. However, if one of the other modes of operation shown in FIGS. 3*a*, 3*b*, 4*a* and 4*b* is desired, the valves 152, 154, 164 and 166 are set as required to apply the proper pressures to the inner ends of the engine and pump pistons 54 and 56. For example, to obtain the mode of operation shown in FIGS. 3*a* and 3*b*, the valve 152 is open, the valve 164 is closed, the valve 154 is closed, and the valve 166 is

open. The mode of operation illustrated in FIGS. 4*a* and 4*b* may be obtained in an analogous manner.)

As hereinbefore suggested, fluid pressure can be applied to the inner ends of the engine and pump sections **44** and **46** in any suitable manner to urge the engine and pump sections **44** and **46** axially outwardly into engagement with the engine and pump valve end walls **78** and **82** of the rotor chamber **24**, thereby assisting the springs **150** in maintaining the desired sealing engagements within the respective engine and pump valve means **74** and **76**. Thus, the springs **150** provide initial sealing engagements which are ultimately supplemented by fluid pressure.

To prevent excessive contact pressures between the engine valve end walls **78** and **80** and the pump valve end walls **82** and **84**, offsetting or balancing fluid pressures may be introduced between the end walls of the respective pairs in the manner described in more detail in my aforementioned copending application. Thus, any desired contact pressures may be obtained for the end walls constituting the engine and pump valve means **74** and **76**.

The engine and pump valve means **74** and **76** are substantially identical to those disclosed in my aforementioned copending application. Briefly, the engine valve means **74**, as shown in FIGS. 5 and 10, comprises ports **168** in the engine valve plate **132** which are aligned with the respective engine cylinders **50** and which are of the same diameter as the engine cylinders to minimize flow resistance. As the rotor **42** rotates, successive ports **168** alternately register with arcuate intake and exhaust ports **170** and **172**, FIGS. 5 and 11, constituting parts of the intake **26** and the exhaust **28** and formed in the engine valve end wall **78** of the rotor chamber **24**. The intake and exhaust ports **170** and **172** have angular extents sufficiently less than 180° that each engine-cylinder port **168** moves out of register with one of the ports **170** and **172** before it moves into register with the other. The pump valve means **76** has essentially the same structure and will not be described.

Turning now to the cam means **68**, the cam **70**, as hereinbefore indicated, comprises a groove formed in the spindle **40** between the engine and pump sections **44** and **46** of the rotor **42**. Preferably, as shown in FIG. 7, the cam groove **70** has dwells **174** which maintain the piston assemblies stationary as the ports **168** move out of register with one of the ports **170** and **172** and into register with the other, and as the corresponding action takes place within the pump valve means **76**. This and other characteristics of the cam groove **70** are fully described in my aforementioned copending application so that a further description herein is not necessary.

As previously indicated, the piston couplings **64** which carry the cam followers **72** are axially slidable in the guide bores **66** in the central rotor section **48**. Consequently, the rotor driving forces developed by the interactions between the cam groove **70** and the cam followers **72** are transmitted directly to the central rotor section **48** through the couplings **64** and the walls of their guide bores **66**, rotation of the central rotor section being transmitted to the engine and pump sections **44** and **46** through the clutches **118** and **120**. Thus, the cam-induced forces for rotating the rotor **42** are not transmitted through the engine and pump pistons **54** and **56**, whereby there is no tendency for these pistons to bind in their respective cylinders **50** and **52**, which is an important feature.

As best shown in FIGS. 8 and 13 of the drawings, each coupling **64** is provided therethrough with a radial slot **176** receiving the leg of a T-shaped cam-follower mounting element **178**. The crossbar of each cam-follower mounting element **178** is seated on a flat **180** on the side of the corresponding coupling **64** opposite the spindle **40**. Screws **182** accessible through longitudinal slots **184** in the central rotor section **48** secure the crossbars of the respective T-shaped mounting elements **178** to the corresponding couplings **64** with the corresponding crossbars seated against the corresponding flats **180**. The crossbars of the mounting elements **178** are axially slidable in the slots **184** in the central rotor section **48**, and the inner ends of the legs of the T-shaped mounting elements are similarly slidable in longitudinal slots **186** in the central rotor section. Thus, the slots **184** and **186** supplement the coupling guiding function performed by the bores **66**.

The cam followers **72** are simply rollers mounted on radial axles **188** in radial bores **190** in the legs of the T-shaped mounting elements **178**. Preferably, the cam followers **72** are truncated cones and the cam groove **70** has a complementary trapezoidal cross section.

It will be noted from FIG. 13 that the engine and pump piston rods **60** and **62** are threaded into the couplings **64**. To permit connecting the piston rods **60** and **62** to and disconnecting same from the couplings **64**, the outer ends of the engine and pump pistons **54** and **56** may be provided with wrench sockets, not shown, or the like, therein. The piston rods **60** and **62** are provided with axial lubrication passages **192** and **194** for conveying fluid from the interior of the barrel **34** to radial ports, not shown, in the engine and pump pistons **54** and **56** for lubrication purposes.

Bottom hole pump of FIGS. 15 to 17

These figures illustrate a bottom hole pump **200** which, for example, may embody the principles of FIG. 3*a*. Structurally, it is very similar to the surface pump **100** so that only a brief description is necessary.

The bottom hole pump **200** includes a housing comprising a cylindrical barrel **202** having engine and pump heads **204** and **206** connected to its upper and lower ends, as by threading. The pump head **206** includes an inlet fitting **208** adapted to seat on a standing valve assembly, not shown, in the conventional manner. The engine head **204** has connected thereto a tube **210** which may be the lower end of a supply tubing for operating fluid under pressure, or which may be the lower end of a packer mandrel, depending on whether the pump **200** is a set pump, or a pump of the type which is hydraulically circulatable between the surface and its operating position in the well through a pump tubing, not shown.

The engine and pump heads **204** and **206** provide therebetween a rotor chamber **212** and carry an axial spindle **214** on which a rotor **216** is mounted. This rotor may be similar to the rotor **42**, except that the bottom hole or well fluid pressure P_0 is applied to the inner or upper ends of the pump pistons, as indicated in FIG. 3*a*. The outer or lower ends of the pump pistons have the bottom hole and column pressures P_0 and P_2 alternately applied thereto, while the outer or upper ends of the engine pistons have the operating fluid pressure and the column pressure P_1 and P_2 alternately applied thereto. The inner or lower ends of the engine pistons have the operating fluid pressure P_1 constantly applied thereto. The manner in which this may be achieved will be apparent from the preceding discussion so that no further description is necessary.

The engine head **204** is provided therein with an intake **218** and an exhaust **220** for the operating fluid and the pump head **206** is provided therein with an inlet **222** and an outlet **224** for the pumped fluid. The intake **218** comprises an axial passage **226** communicating with ports **228** leading to an arcuate intake port **230** corresponding to the intake port **170**. The exhaust **220** comprises an arcuate exhaust port **232** corresponding to the exhaust port **172** and communicating with passages **234** terminating in radial ports **236**. The ports **236** may communicate with a suitable tubing, not shown, for conveying the spent operating fluid to the surface.

The inlet **222** comprises an axial passage **238** extending upwardly to an arcuate inlet passage **240** terminating in an arcuate inlet port **242**. The outlet **224** comprises an arcuate outlet port **244** communicating with longitudinal passages **246** terminating at their lower ends in radial ports **248**. The latter are adapted to communicate with a tub-

ing, not shown, for conveying pumped or production fluid upwardly to the surface. This tubing may be the same as or different from the tubing for conveying spent operating fluid upwardly to the surface, depending upon whether an open or closed pumping system is desired.

Although exemplary embodiments of the present invention have been disclosed herein for purposes of illustration, it will be understood that various changes, modifications and substitutions may be incorporated in such embodiments without departing from the spirit of the invention as defined by the claims which follow.

I claim as my invention:

1. In a rotary fluid operated pump, the combination of:
(a) a housing provided therein with a rotor chamber and having an intake and an exhaust for operating fluid and an inlet and an outlet for fluid being pumped;
(b) a sectional rotor in and rotatable about the axis of said rotor chamber and including engine and pump end sections and a central section;
(c) two disengageable coupling means respectively coupling said end sections to said central section in torque transmitting relation, and respectively comprising interengageable coupling elements on the ends of said central section of said rotor and adjacent ends of said end sections thereof;
(d) said engine end section being provided therein with circumferentially spaced engine cylinders having axes paralleling the axis of said rotor chamber;
(e) said pump end section being provided therein with circumferentially spaced pump cylinders respectively aligned with said engine cylinders;
(f) engine pistons respectively reciprocable in said engine cylinders;
(g) pump pistons respectively reciprocable in said pump cylinders;
(h) piston connecting means extending through said central section and respectively interconnecting said engine pistons and said pump pistons;
(i) cam means responsive to reciprocatory movement of said interconnected engine and pump pistons for rotating said rotor about the axis of said rotor chamber;
(j) engine valve means responsive to rotation of said rotor for sequentially connecting said engine cylinders to said intake and said exhaust alternately: and
(k) pump valve means responsive to rotation of said rotor for sequentially connecting said pump cylinders to said inlet and said outlet alternately.

2. In a rotary fluid operated pump, the combination of:
(a) a housing provided therein with a rotor chamber having engine and pump valve end walls, and provided with an intake and an exhaust for operating fluid and an inlet and an outlet for fluid being pumped;
(b) a spindle carried by said housing within and extending axially of said rotor chamber;
(c) a sectional rotor in said rotor chamber and rotatably mounted on said spindle and including engine and pump end sections and a central section;
(d) two disengageable coupling means respectively coupling said end sections to said central section in torque transmitting relation, and respectively comprising interengageable coupling elements on the ends of said central section of said rotor and adjacent ends of said end sections thereof;
(e) said engine end section being provided therein with circumferentially spaced engine cylinders having axes paralleling the axis of said rotor chamber;
(f) said pump end section being provided therein with circumferentially spaced pump cylinders respectively aligned with said engine cylinders;
(g) engine pistons respectively reciprocable in said engine cylinders;
(h) pump pistons respectively reciprocable in said pump cylinders;
(i) piston connecting means extending through said central section nad respectively interconnecting said engine pistons and said pump pistons;
(j) cam means on said piston connecting means and said spindle and responsive to reciprocatory movement of said interconnected engine and pump pistons for rotating said rotor about the axis of said rotor chamber;
(k) engine valve means formed by said engine valve end wall of said rotor chamber and an adjacent engine valve end wall of said engine end section of said rotor, and responsive to rotation of said rotor, for sequentially connecting said engine cylinders to said intake and said exhaust alternately; and
(l) pump valve means formed by said pump valve end wall of said rotor chamber and an adjacent pump valve end wall of said pump end section of said rotor, and responsive to rotation of said rotor, for sequentially connecting said pump cylinders to said inlet and said outlet alternately.

3. A rotary fluid operated pump as defined in claim 2 including means for biasing said engine and pump end sections of said rotor axially away from said central section thereof and into engagement with said engine and pump valve end walls, respectively, of said rotor chamber.

4. A rotary fluid operated pump as set forth in claim 3 wherein said biasing means includes spring means acting between said central section of said rotor and said engine and pump end sections thereof.

5. A rotary fluid operated pump according to claim 2 wherein said disengageable coupling means include clutch jaws on adjacent end walls of said central section of said rotor and said engine and pump end sections thereof.

6. A rotary fluid operated pump as defined in claim 2 wherein said engine and pump valve end walls of said engine and pump end sections of said rotor are respectively formed by separate engine and pump valve plates, said engine and pump end sections carrying circumferentially spaced, axially extending bolts respectively connecting said engine and pump valve plates thereto.

7. A rotary fluid opreated pump as set forth in claim 2 wherein said housing includes a cylindrical barrel containing said rotor and includes heads secured to and closing the ends of said barrel and defining said engine and pump valve end walls of said rotor chamber, said spindle being mounted on said heads.

8. A rotary fluid operated pump according to claim 2 wherein said cam means includes a cam groove in said spindle and includes cam followers carried by said piston connecting means and extending radially inwardly into said cam groove.

9. In a rotary fluid operated pump, the combination of:
(a) a housing provided therein with a rotor chamber and having an intake and an exhaust for operating fluid and an inlet and an outlet for fluid being pumped;
(b) a spindle carried by said housing within and extending axially of said rotor chamber;
(c) a rotor in said rotor chamber and rotatably mounted on said spindle;
(d) said rotor being provided in one end thereof with circumferentially spaced engine cylinders having axes paralleling the axis of said rotor chamber and being provided in the other end thereof with circumferentially spaced pump cylinders respectively aligned with said engine cylinders;
(e) engine pistons respectively reciprocable in said engine cylinders;
(f) pump pistons respectively reciprocable in said pump cylinders;
(g) piston connecting means respectively interconnecting said engine pistons and said pump pistons;
(h) each of said piston connecting means including a coupling and including piston rods extending axially from the corresponding engine and pump pistons and threadedly connected to said coupling;

(i) guide means on said rotor and engaging said couplings for constraining said couplings against radial and circumferential movement relative to said rotor and for guiding said couplings for movement relative to said rotor along paths paralleling the axis of said rotor chamber in response ot reciprocatory movement of the interconnected engine and pump pistons;

(j) cam means on said couplings and said spindle and responsive to reciprocatory movement of said interconnected engine and pump pistons for rotating said rotor about the axis of said rotor chamber;

(k) engine valve means responsive to rotation of said rotor for sequentially connecting said engine cylinders to said intake and said exhaust alternately; and

(l) pump valve means responsive to rotation of said rotor for sequentially connecting said pump cylinders to said inlet and said outlet alternately.

10. A rotary fluid operated pump according to claim **9** wherein said cam means includes a cam on said spindle and cam followers respectively carried by said couplings and extending radially inwardly into engagement with said cam.

11. A rotary fluid operated pump as set forth in claim **10** wherein said cam is a groove in said spindle and wherein said cam followers comprise rollers in said cam groove.

12. A rotary fluid operated pump as set forth in claim **11** including cam-follower mounting elements detachably connected to said couplings, said cam followers being carried by said cam-follower mounting elements, respectively.

13. A rotary fluid operated pump as defined in claim **12** wherein said couplings are provided with slots therethrough which are oriented radially relative to the axis of said rotor chamber, said cam-follower mounting elements being disposed in said slots, respectively.

14. A rotary fluid operated pump according to claim **9** wherein said couplings are substantially cylindrical and wherein said guide means comprises circumferentially spaced bores in said rotor having axes paralleling the axis of said rotor chamber and slidably receiving said couplings therein, respectively.

15. A rotary fluid operated pump as set forth in claim **14** wherein said cam means includes a cam on said spindle and cam followers respectively carried by said couplings and extending radially inwardlly into engagement with said cam.

16. A rotary fluid operated pump as defined in claim **15** including cam-follower mounting elements respectively carried by said couplings and respectively carrying said cam followers, said rotor being provided therein with guides paralleling the axis of said rotor chamber and slidably engaging portions of said cam-follower mounting elements.

17. In a rotary fluid operated pump, the combination of:

(a) a housing provided therein with a rotor chamber;

(b) a spindle carried by said housing within and extending axially of said rotor chamber;

(c) a rotor in said rotor chamber and rotatably mounted on said spindle;

(d) said rotor being provided in one end thereof with circumferentially spaced engine cylinders having axes paralleling the axis of said rotor chamber and being provided in the other end thereof with circumferentially spaced pump cylinders respectively alinged with said engine cylinders;

(e) engine pistons respectively reciprocable in said engine cylinders;

(f) pump pistons respectively reciprocable in said pump cylinders;

(g) piston connecting means respectively interconnecting said engine pistons and said pump pistons;

(h) guide means on said rotor and encompassing and engaging said piston connecting means, respectively, for constraining said piston connecting means against radial inward and outward movement and circumferential movement relative to said rotor and for guiding said piston connecting means for longitudinal movement relative to said rotor along paths paralleling the axis of said rotor chamber in response to reciprocatory movement of the interconnected engine and pump pistons;

(i) interengaged cam means on said piston connecting means and said spindle and responsive to reciprocatory movement of said interconnected engine and pump pistons for rotating said rotor about the axis of said rotor chamber, said cam means on said piston connecting means extending radially inwardly through said guide means into engagement with said cam means on said spindle;

(j) means for admitting operating fluid under pressure into and exhausting spent operating fluid from successive ones of said engine cylinders as said rotor rotates; and

(k) means for admitting fluid to be pumped into and discharging pumped fluid from successive ones of said pump cylinders as said rotor rotates.

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