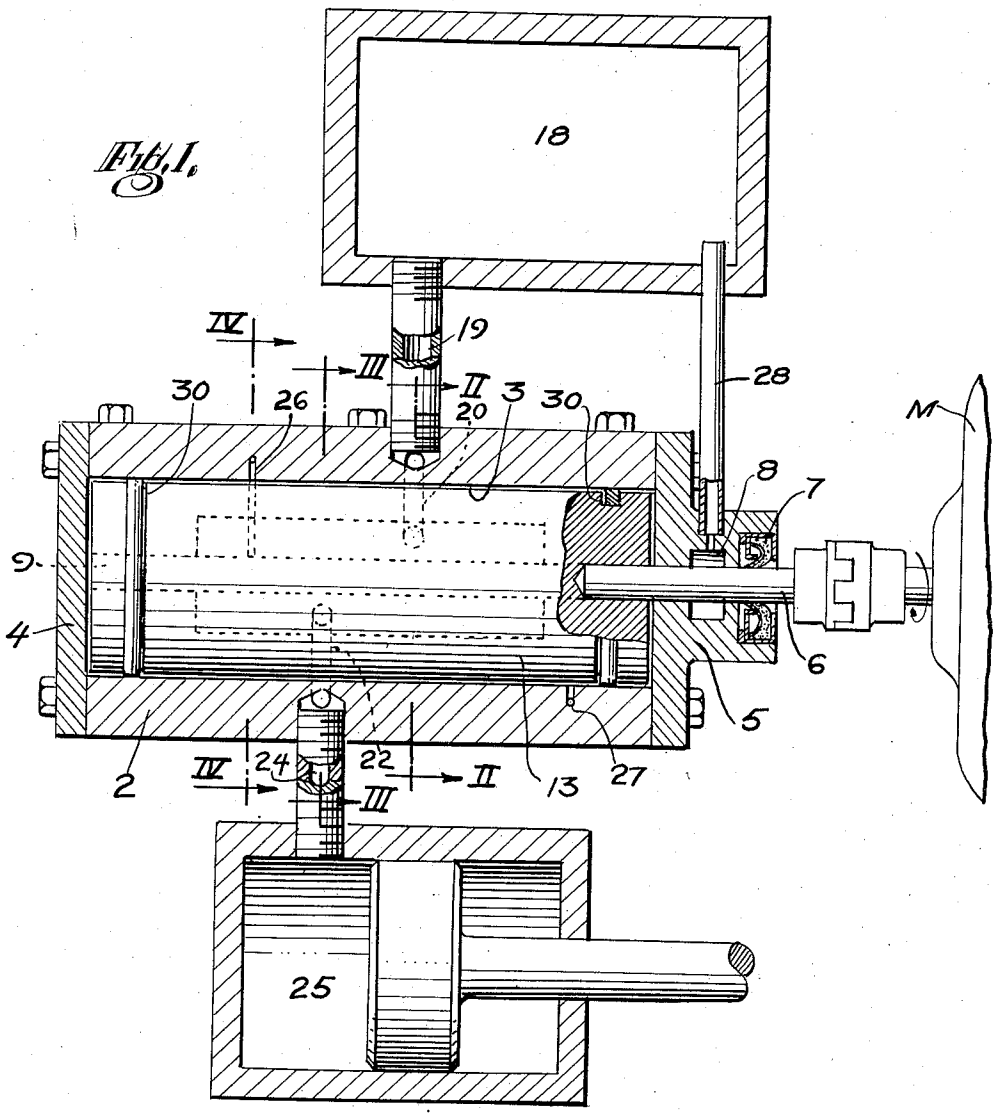
Jan. 15, 1957 J. MODROVSKY ET AL 2,777,394

PUMP FOR VISCOUS FLUIDS

Filed Oct. 27, 1954 3 Sheets-Sheet 1

Fig. 1.



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Filed Oct. 27, 1954 3 Sheets-Sheet 2

Fig. 2.

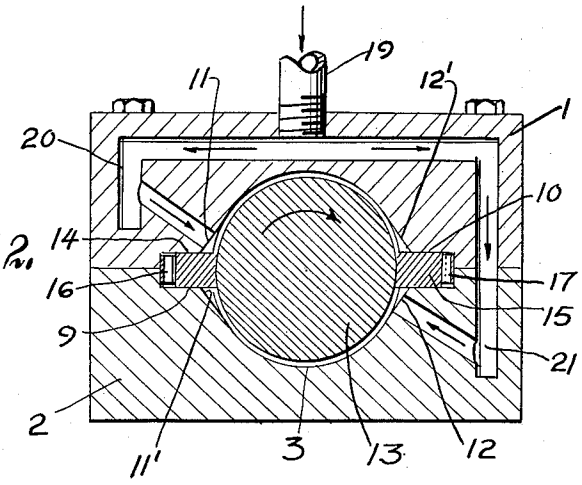


Fig. 3.

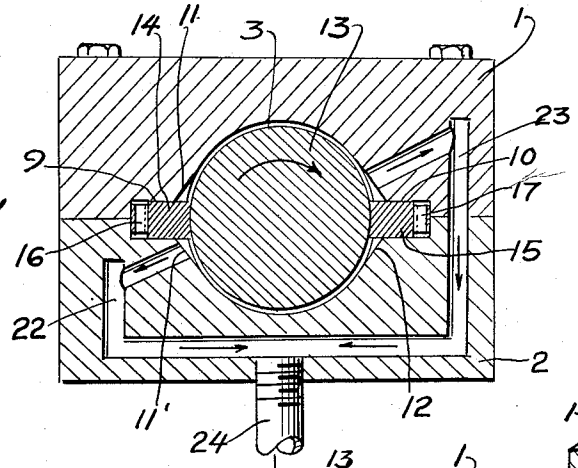


Fig. 4.

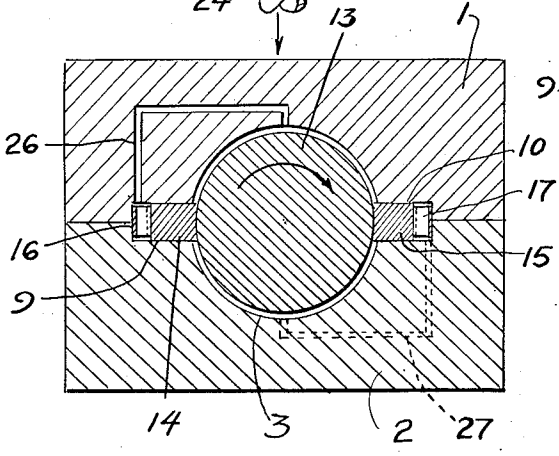
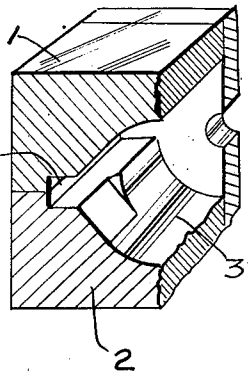


Fig. 5.



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Filed Oct. 27, 1954 3 Sheets-Sheet 3

Fig. 6.

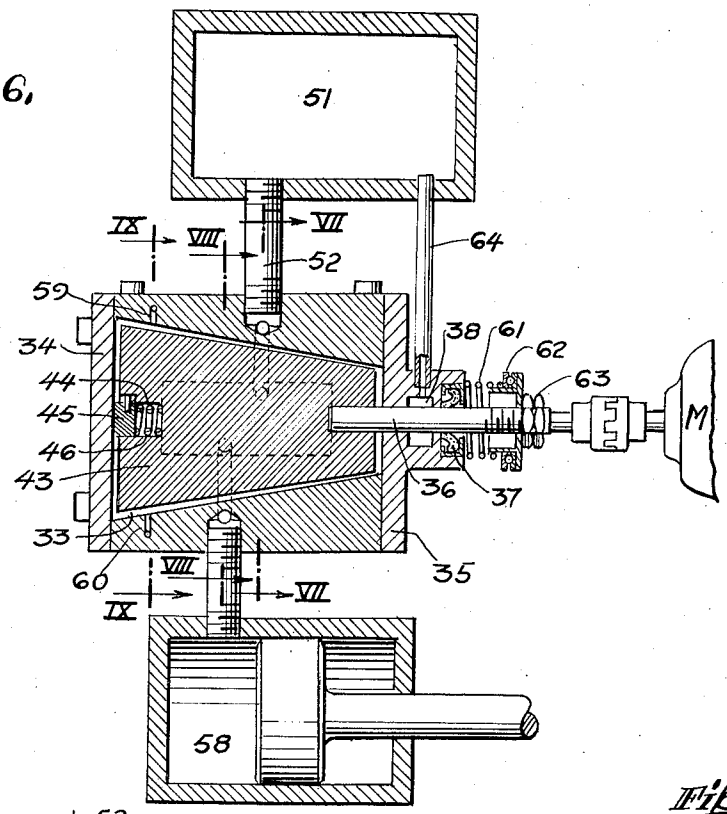


Fig. 7.

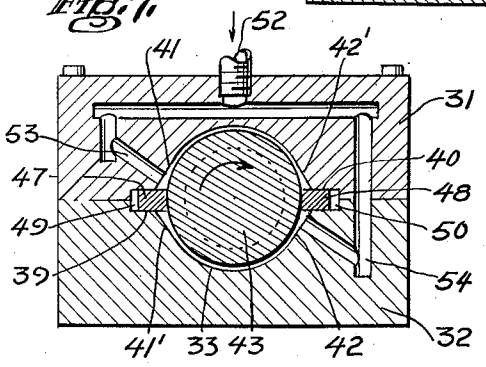


Fig. 8.

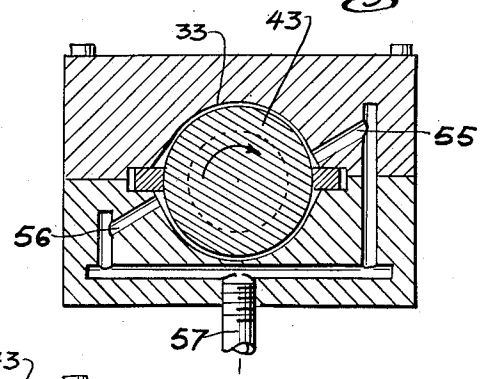
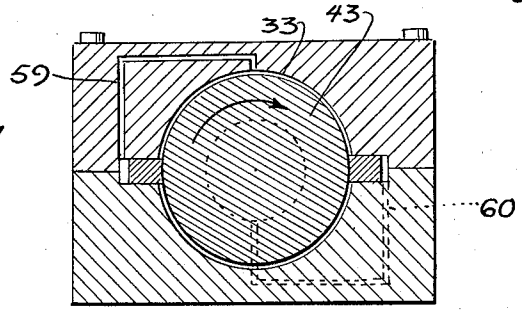


Fig. 9.



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United States Patent Office 2,777,394 Patented Jan. 15, 1957

2,777,394

PUMP FOR VISCOUS FLUIDS

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Application October 27, 1954, Serial No. 465,078

13 Claims. (Cl. 103—84)

This invention relates to a pump for viscous fluids characterized by the ability to deliver quantities of fluid at high pressures.

An object of the invention is to utilize the shear resistance of the fluid as a major causational factor in creating a pressure condition.

Another object is to provide such a pump including a rotor and a stator, in which the rotor cannot be stalled by any load.

A further object is to provide a pump in which the rotor may be a plain cylindrical or frusto-conical body rotating on its axis.

A still further object is to provide a pump which has no valves, is completely reversible, can be operated at high speeds, is corrosion resistant and is silent.

Another object is to provide certain improvements in the form, construction and arrangement of the parts, whereby the above-named and other objects may effectively be attained.

Practical embodiments of the invention are represented in the accompanying drawings, in which:

Fig. 1 represents a vertical section on the axis of the pump with cylindrical rotor, the fluid supply and utilization elements being shown diagrammatically;

Fig. 2 represents a section on the line II—II of Fig. 1, looking in the direction of the arrows;

Fig. 3 represents a section on the line II—III of Fig. 1, looking in the direction of the arrows;

Fig. 4 represents a section on the line IV—IV of Fig. 1, looking in the direction of the arrows;

Fig. 5 represents, in perspective, a detail segment of one corner of the pump chamber, parts being cut away;

Fig. 6 represents a vertical section on the axis of the modified form of pump in which the rotor is frusto-conic, the fluid supply and utilization elements being shown diagrammatically, as in Fig. 1;

Fig. 7 represents a section on the line VII—VII of Fig. 6, looking in the direction of the arrows;

Fig. 8 represents a section on the line VIII—VIII of Fig. 6, looking in the direction of the arrows, and

Fig. 9 represents a section on the line IX—IX of Fig. 6, looking in the direction of the arrows.

Referring to the drawings, and particularly Figs. 1 to 5 thereof, the pump is shown as comprising a cylinder block formed by upper and lower complementary halves 1, 2, having a cylindrical bore 3 formed therein. The bore 3 is tightly closed at one end of the head 4, while the opposite end is closed by the head 5 in which is journaled the rotor drive shaft 6; a shaft seal is indicated at 7 and the shaft is surrounded, between the seal and the interior of the cylinder, by an annular recess 8 constituting a spill-way. The shaft is connected in a suitable manner to a source of power, indicated generally as the motor M.

The cylinder wall is provided with radially extended slots 9, 10 along opposite sides and in an axial plane, and the cylinder wall is beveled slightly (as indicated at 11, 11', 12, 12') adjacent its intersection with the said slots and throughout a distance terminating short of the cylinder ends (see Fig. 5). A rotor 13, in the form of a plain cylindrical body is mounted on the drive shaft 6 and has a diameter giving it approximately a free fit in the cylinder and a length such that the end clearance, between the rotor and the heads 4 and 5, is as small as possible without appreciable friction.

Each slot 9, 10 is occupied by a doctor blade or vane 14, 15, respectively, preferably of metallic or non-metallic anti-friction material and shaped to bear lightly against the surface of the rotor along narrow, diametrically opposite, zones extending the full length of the cylinder. The blades 14, 15 may be urged into engagement with the rotor by means of springs 16, 17 alone or in combination with hydraulic means described below.

Fluid inlet conduits are shown in Fig. 2, the supply system including a reservoir 18 (Fig. 1), a main inlet pipe 19 and conduits 20, 21 drilled in the cylinder block to conduct fluid, respectively, to beveled zones 11 and 12. Assuming the rotation of the rotor to be in the direction indicated, said zones are on the downstream sides of the doctor blades. The fluid outlet system, shown in Fig. 3 is approximately the converse of the inlet system, comprising conduits 22, 23, disposed so as to conduct the fluid from the beveled zones 11' and 12', respectively, to the outlet pipe 24, whence the fluid under pressure passes to any desired utilization apparatus, represented by the cylinder and piston 25 in Fig. 1. It will be noted that the zones 11' and 12' are on the upstream sides of the respective doctor blades.

Since it is reasonable for the doctor blades to be urged against the rotor with a force roughly proportional to the fluid pressure being developed in the pump, small additional conduits 26, 27 are provided to draw off fluid from points intermediate the blades (in the circumferential direction) and to feed such fluid into the slots 9, 10, in back of the respective blades. As shown, each such tap-off is located midway between the blades, but other locations may be adopted if desired.

In operation, the reservoir 18 is provided with a quantity of fluid, such as oil of any desired viscosity, capable of flowing through the supply system 19, 20, 21 to the beveled zones 11, 12 in the cylinder. The rotor is rotated, in the direction of the arrows (Figs. 2, 3 and 4), and the fluid in the zones 11, 12 is carried by the moving surface of the rotor in the direction of rotation thereof. The beveled zones 11' and 12' become filled with fluid almost instantly, as the fluid is moved toward them and because the circumferential flow is completely stopped by the blades 14, 15. As soon as the said zones are filled, the continuing effort of fluid entrained by the rotor and engaged therewith through its inherent viscosity, to follow the movement of the rotor surface results in a building up of pressures in said zones. The fluid under pressure is adapted to be drawn off through the conduits 22, 23 and pipe 24, for utilization as may be desired. The pressure build-up extends back from the pressure zones a sufficient distance so that fluid under some pressure will pass through the conduits 26, 27 and will, as the pressure increases, hold the doctor blades more and more firmly against the rotor surface, supplementing or even supplanting the action of springs 16, 17.

The presence of fluid in the clearance at the ends of the rotor is unimportant except as it may thus asssit in lubricating the parts. Any such fluid which may leak out of the cylinder along the drive shaft is collected in the spillway recess 8 and may readily be returned, at low pressure, to the reservoir 18 through a pipe 28 (Fig. 1). Endwise leakage can be minimized, particularly when high pressure operation is contemplated, by the provision of end seals of any type which will not add an undesirable friction factor; in Fig. 1 such seals are shown as being piston rings 29 seated in grooves 30.

The values of pressures developed by this pump are affected by several factors, including viscosity of the fluid, compatability of the fluid with the surfaces of the cylinder and the rotor, minimum clearance between said surfaces, and surface speed of the rotor. The pressure will reach a maximum for any given set of factors, and will be maintained at that maximum, so long as the rate of delivery through the outlet system remains less than the rate at which the fluid is capable of being fed to the pressure zones. Control of the delivery can be exercised by means of a valve of any customary type (not shown) on the outlet pipe **24**. It will be apparent that the pump cannot be stalled, even when such a valve is closed completely, and that the pump can be driven at a constant rate and under substantially constant load to deliver fluid constantly or intermittently in quantities and at pressures within the predetermined limits.

The pump here shown and described has two doctor blades and two diametrically opposed pressure zones connected in parallel to the supply and delivery systems. The forces acting on the rotor surfaces are symmetrical, so that tendencies toward eccentricity are minimized. If one of the doctor blades and the adjacent beveled zones of the cylinder are eliminated it will be found that higher pressures with lower delivery rate can be obtained while the rotor is subjected to unbalanced radial forces originating in the single pressure zone. On the other hand, any plurality of doctor blades and pressure zones, uniformly spaced around the rotor, will constitute a balanced system; as the number is increased the possible maximum pressure becomes less and the rate of delivery becomes greater. The pump is fully reversible; upon rotating the rotor in the opposite direction the functions of the input and output systems are interchanged, with reverse opereation in the same manner and with the same efficiency.

In the modified form of pump shown in Figs. 6 to 9 the cylinder block is formed by upper and lower complementary halves **31**, **32**, having a frusto-conic chamber **33** formed therein. The chamber is closed at its larger end by the head **34** and the smaller end is closed by the head **35** in which is journaled the rotor drive shaft **36**. A conventional shaft seal is indicated at **37**, and there is formed around the shaft, between the seal and the interior of the cylinder, an annular recess **38**. The shaft is intended to be driven, as before, by a motor M.

The chamber wall is radially slotted at **39**, **40** along diametrically opposite lines and in an axial plane, and the chamber wall is preferably beveled slightly, at **41**, **41'**, **42**, **42'**, adjacent its intersection with said slots and for a distance terminating short of the ends of the chamber, comparable to the arrangement of which a detail is shown in Fig. 5. In this modification the rotor **43**, mounted on the drive shaft **36**, is frusto-conic in form, and preferably tapers slightly less steeply than the walls of the chamber (at least throughout a distance corresponding to the axial length of the beveled zones **41**, **41'**, **42**, **42'**), the diameter of the small end of the rotor being no less than the diameter of the chamber at its smaller end and the length of the rotor being sufficiently less than the length of the chamber to provide a substantial clearance at either or both ends, depending upon the axial position of the rotor in the chamber. The larger end of the rotor is provided with a central bore **44** in which is fitted a movable ball or plug **45** urged outwardly by the spring **46** so as to bear against the head **34**. The rotor is capable of slight motion in the axial direction, resulting in variation in the clearance between the frusto-conic surfaces of the rotor and stator, and the parts **45**, **46** are designed to urge the rotor in the direction of reduced clearance.

Each slot **39**, **40** is occupied by a doctor blade or vane **47**, **48** respectively, preferably of metallic or non-metallic anti-friction material and shaped to bear lightly against the surface of the rotor along narrow, diametrically opposite, zones extending the full length of the chamber. The blades **47**, **48** may be urged into engagement with the rotor by means of springs **49**, **50** alone or in combination with hydraulic means as in the case of the blades **14**, **15**.

Fluid inlet conduits are shown in Fig. 7, the supply system including a reservoir **51** (Fig. 6), a main inlet pipe **52** and conduits **53**, **54** drilled in the block to conduit fluid, respectively, to beveled zones **41** and **42**. Assuming the rotation of the rotor to be in the direction indicated, said zones are on the downstream sides of the doctor blades. The fluid outlet system, shown in Fig. 8 is approximately the converse of the inlet system, comprising conduits **55**, **56**, disposed so as to conduct the fluid from the beveled zones **41'** and **42'**, respectively, to the outlet pipe **57** whence the fluid under pressure passes to any desired utilization apparatus, represented by the cylinder and piston **58** in Fig. 6. It will be noted that the zones **41'** and **42'** are on the upstream sides of the respective doctor blades.

Small additional conduits **59**, **60** (Fig. 9) are provided to draw off fluid from points intermediate the blades (in the circumferential direction) and to feed such fluid into the slots **39**, **40**, in back of the respective blades, in order to supplement (or supplant) the action of springs **49**, **50**.

In addition to (or instead of) the spring **46** and plug **45**, it may be desirable to provide a spring **61** bearing against the head **35** and, through a thrust bearing **62**, against a stop **63** on the drive shaft **36**. Means for adjusting the degree to which this spring is compressed may be provided, for instance, by making the stop **63** in the form of a nut threaded on the drive shaft. The pipe **64** connects the chamber **38** with the reservoir **51**, serving the same function as the pipe **28** in Fig. 1.

The operation of this form of the pump is basically the same as described above in connection with the pump of Figs. 1 to 5. The tapering form of the rotor and chamber do, however, introduce certain additional considerations. Since the pressure developed in the field responds to the law:

$$P \propto \frac{\mu A V}{h^2} \text{ and } V \propto N \text{ (Dia)}$$

where

μ=viscosity
A=surface area
V=surface velocity
h=clearance

$\therefore$ to obtain constant pressure along the rotor (i. e., from end to end of the beveled zones **41'**, **42'**), taking D_1=large end diameter, and D_2=small end diameter, then

$$\frac{D_1}{h_1}=\frac{D_2}{h_2} \text{ or } \frac{D_1}{D_2}=\frac{h_1}{h_2}$$

so that the rotor surface should taper less steeply than the stator chamber surface, as previously stated, providing increased clearance toward the large end, in order that the pressure may be developed approximately uniformly along the rotor.

The axial component of fluid pressure tends to move the rotor in the direction of increased clearance, this force being counterbalanced to a predetermined extent by the force of the springs **46** and/or **61**. Since an increase of fluid pressure can cause axial movement of the rotor, it is evident that the arrangement shown tends to produce fluid pressure which is automatically stabilized at approximately a constant value. If adjustability is not required, the spring **61** and its associated parts may be omitted, leaving to the spring **46** the entire function of counterbalancing the axial pressure component. On the other hand, when the spring **61** is present the elements **44**, **55** and **46** may be omitted, for instance, in pumps of certain sizes or for certain purposes.

As with the first shown form of pump, the tapering rotor pump may be made with more than two doctor

blades or with only one, and is fully reversible. Except as noted, the two forms of the pump are subject to substantially the same remarks and exhibit comparable advantages.

It is known that certain surface treatments have the effect of varying the compatability or "bond" between fluids, such as oils, and solid surfaces. Aside from physical roughening or smoothing of a surface the presence or absence of certain greases is a factor, or film-forming materials such as the Swiss product called "Aretol" can be used—said product having the effect of preventing the spreading of oil film, i. e., being oleophobic. The synthetic plastic known as "Teflon" (Du Pont) has a similar effect. In general, greater pressures, volumes and efficiencies are obtained in a pump wherein the rotor surface has greater compatability for the fluid (oil) than has the stator surface.

In the pumps shown, the shear resistance and fluid wedge effect are utilized at their highest efficiency, in that the doctor blades constitute positive stops for the entrained fluid. If desired, the rotor of Figs. 6–9 may be mounted on a drive shaft at its larger end, requiring only obvious modifications in the spring or springs. Although the structure is described herein as a pump, it has been found that the operation is reversible; that is, the device can be operated as a motor by supplying fluid under pressure and thus causing the rotor to rotate.

What we claim is:

1. A pump for viscous fluids comprising, a fixed member having a surface the radial sections of which are circular, a rotatable member having a complementary surface also circular in section, concentric and interfitting with said first named surface with a clearance therebetween, at least one radially floating elongated axially disposed abutment slidably mounted in said fixed member, means acting to urge said abutment resiliently and continuously against the surface of said movable member along at least a major part of a generatrix of said surface, means for rotating the rotatable member, means for conducting fluid from a source of supply to the said clearance at a point downstream from each said abutment considered circumferentially with respect to the direction of rotation of the rotatable member, and means for withdrawing the fluid under pressure from a point adjacent to, and upstream from, each said abutment.

2. A pump according to claim 1 in which there are a plurality of abutments.

3. A pump according to claim 1 in which said surfaces are cylindrical.

4. A pump according to claim 3 in which the cylindrical surface of the fixed member defines a chamber within which the rotatable member is contained.

5. A pump according to claim 1 in which said surfaces are frusto-conic.

6. A pump according to claim 5 in which the frusto-conic surface of the fixed member defines a chamber within which the rotatable member is contained.

7. A pump for viscous fluids comprising, a fixed member provided with a cylindrical chamber, cylinder heads closing both ends of said chamber, a drive shaft journaled in one of said cylinder heads on the axis of said chamber, a cylindrical rotor having its surface concentric and interfitting with the surface of the chamber with a clearance therebetween and being mounted on the drive shaft, at least one radially movable doctor blade mounted in a slot extending axially along the chamber wall for a substantial distance, means urging said blade toward said rotor surfce, means for conducting fluid from a source of supply to the said clearance at a point downstream from each said doctor blade and means for withdrawing fluid under pressure from a point adjacent to, and upstream from, each said doctor blade.

8. A pump according to claim 7 in which the blade-urging means includes a fluid circuit so disposed as to conduct pressure fluid from a point in the clearance spaced from any doctor blade to the slot in which a doctor blade is mounted.

9. A pump for viscous fluids comprising, a fixed member provided with a frusto-conic chamber, cylinder heads closing both ends of said chamber, a drive shaft journaled in one of said cylinder heads on the axis of said chamber, a frusto-conic rotor having its surface concentric and interfitting with the surface of the chamber with a clearance therebetween and being mounted on the drive shaft, at least one radially movable doctor blade mounted in a slot extending axially along the chamber wall for a substantial distance, means urging said blade toward said rotor surface, means for conducting fluid from a source of supply to the said clearance at a point downstream from each said doctor blade and means for withdrawing fluid under pressure from a point adjacent to, and upstream from, each said doctor blade.

10. A pump according to claim 9 in which the blade-urging means includes a fluid circuit so disposed as to conduct pressure fluid from a point in the clearance spaced from any doctor blade to the slot in which a doctor blade is mounted.

11. A pump according to claim 9 in which the rotor surface is less steeply tapered than the chamber surface.

12. A pump according to claim 9 in which the rotor is axially movable and which includes means urging the rotor in the direction of closer engagement with the chamber surface.

13. A pump according to claim 12 in which the rotor surface is less steeply tapered than the chamber surface.

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