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Wisniewski et al.

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[45] **July 16, 1974**

[54] **VARIABLE-CAPACITY SLIDING-VANE PUMP**

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[21] Appl. No.: **226,681**

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[52] **U.S. Cl.** **418/30,** 418/31, 418/148, 418/266, 418/16, 418/39, 418/267

[51] **Int. Cl.** **F04c 15/04**

[58] **Field of Search** 418/16, 30, 31, 148, 147, 418/140, 179, 266, 267, 269

[56] **References Cited**

UNITED STATES PATENTS

1,389,466	8/1921	White	418/16
1,776,452	9/1930	Rosenthal	418/148
2,052,492	8/1936	Seibold	123/8.45
2,135,760	11/1938	Moore	418/31
2,387,761	10/1945	Kendrick	418/16 X
2,463,118	3/1949	Moore	418/148 X
2,612,110	9/1952	Delegard	418/16 UX
2,612,115	9/1952	Ernst	418/16 X
2,804,016	8/1957	Moore	418/31 X
2,842,064	7/1958	Wahlmark	418/31
3,234,816	2/1966	Von Thuengen	418/16 X
3,263,912	8/1966	Frenzel	418/179 UX
3,334,546	8/1967	Vuolle-Apiala	418/16 X
3,452,725	7/1969	Kelly	123/8.45 X

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Attorney, Agent, or Firm—Stevens, Davis, Miller & Mosher

[57] **ABSTRACT**

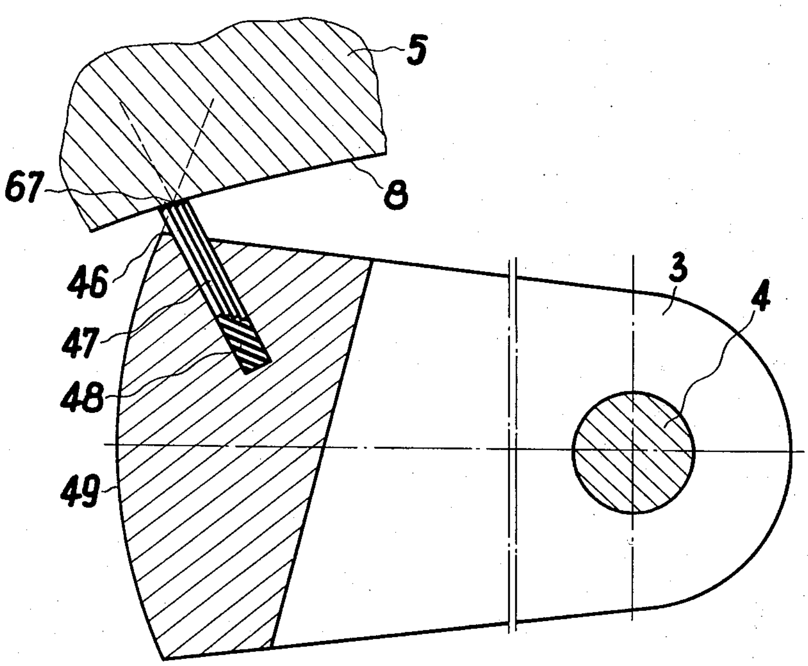
The invention relates to a technical solution of a double-acting, thus relieved, sliding-vane pump, its capacity being adjustable in a continuous way during operation of the pump.

The adjustment of the capacity of said pump is performed at constant speed of the pump rotor, by means of turning a movable cylinder, movable inlet and outlet chambers, or by deformation of a flexible cylinder, relatively to the modification of the pump.

Said pumps can have pendulous vanes mounted non-centrically on shafts, or rotatively, or artitulatively mounted in channels of the rotor, or rotatively and centrically mounted on shafts.

The vanes mounted in all the modification of the pump are provided with seals at the contact areas with the cylinder, and in channels of the rotor. The seal of the vane against the cylinder is realized by means of a plate pack, pushed out individually by an elastic and flexible material. The sealing of the vane in the rotor is secured by means of a rubber bar or elastic thin-walled seal with spread arms.

3 Claims, 15 Drawing Figures



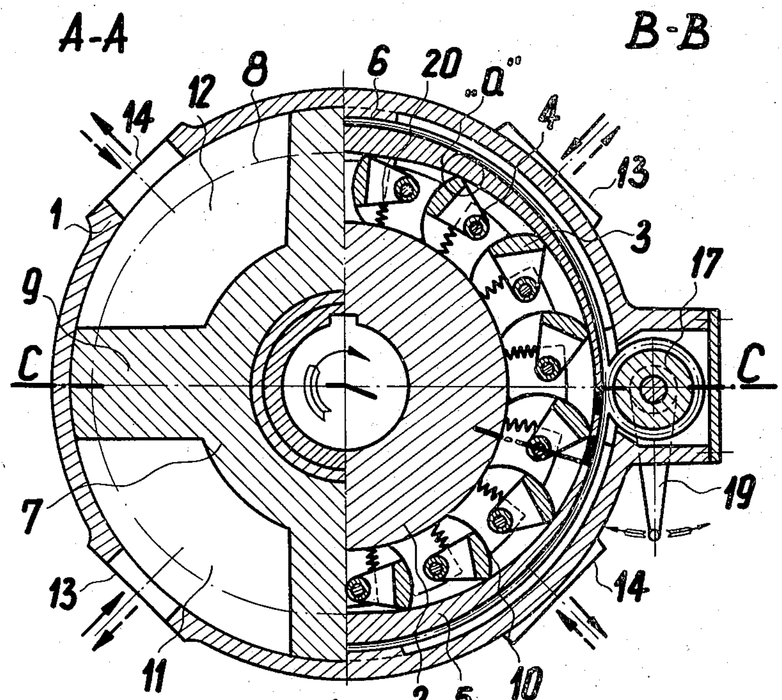

A-A
B-B
8
6
20
"a"
12
14
4
13
1
3
17
9
C
C
19
7
13
14
11
2
5
10

Fig. 1

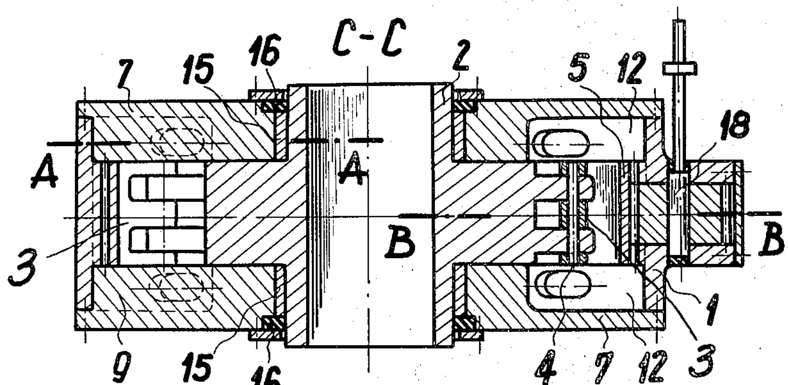

C-C
7
15
16
2
5
12
18
A
A
3
B
B
1
9
15
16
4
7
12
3

Fig. 2

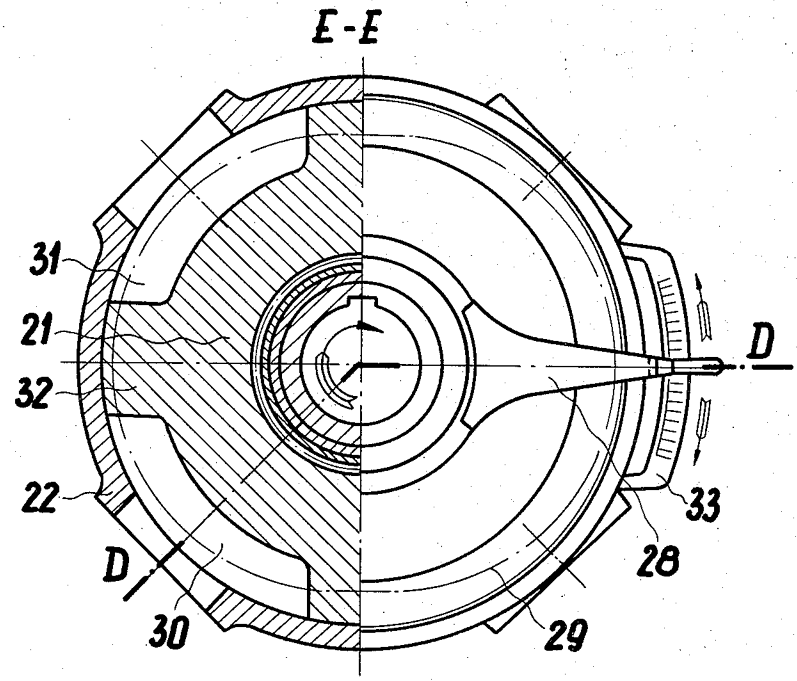

E-E
31
21
32
22
D
30
D
33
28
29

Fig. 3

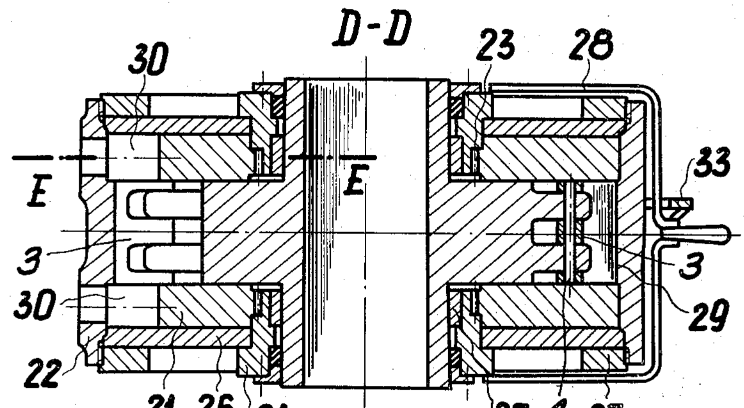

D-D
30
23
28
E
E
33
3
3
30
29
22
21
26
24
25
4
27

Fig. 4

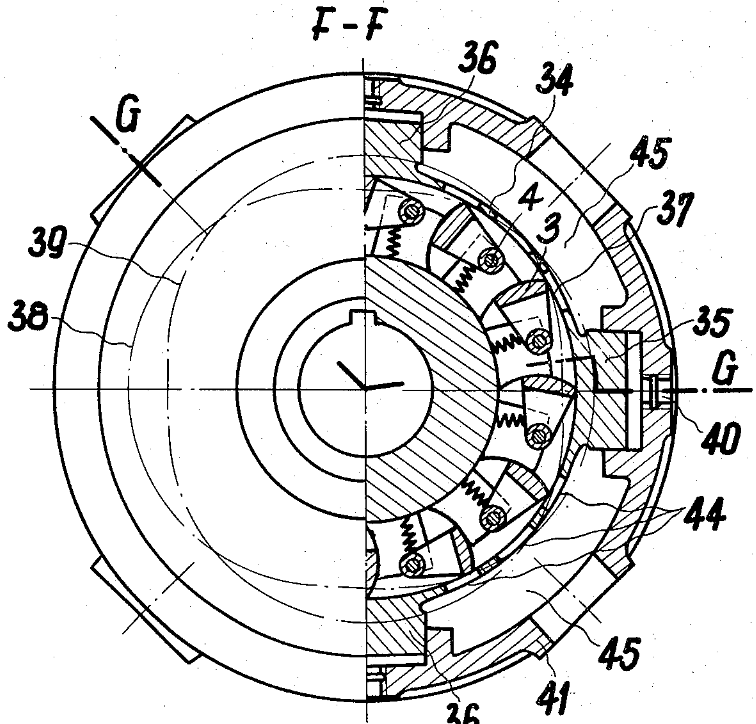

F-F
G
36
34
45
4
3
37
39
38
35
G
40
44
45
41
36

Fig. 5

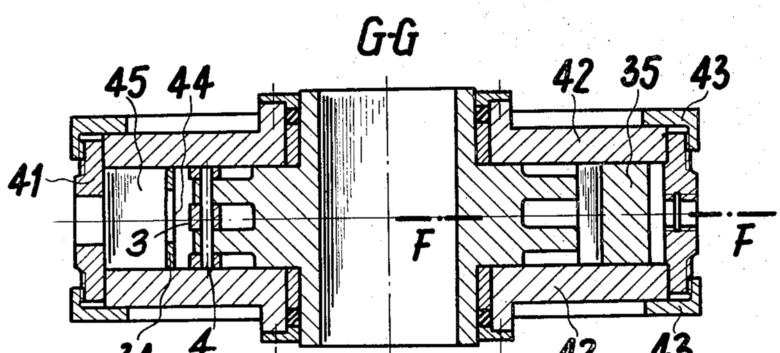

G-G
45
44
42
35
43
41
3
F
F
34
4
42
43

Fig. 6

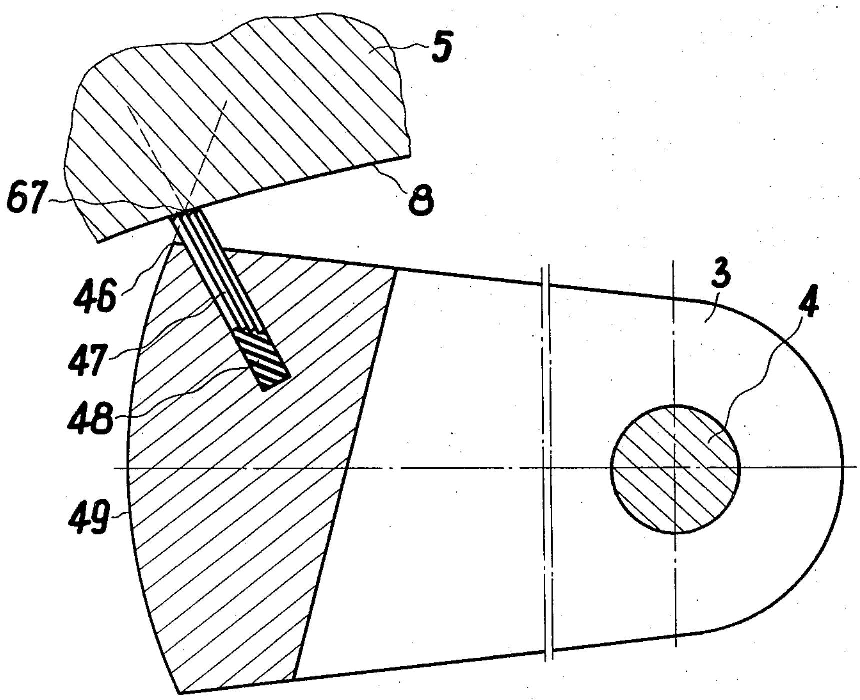


Fig. 7

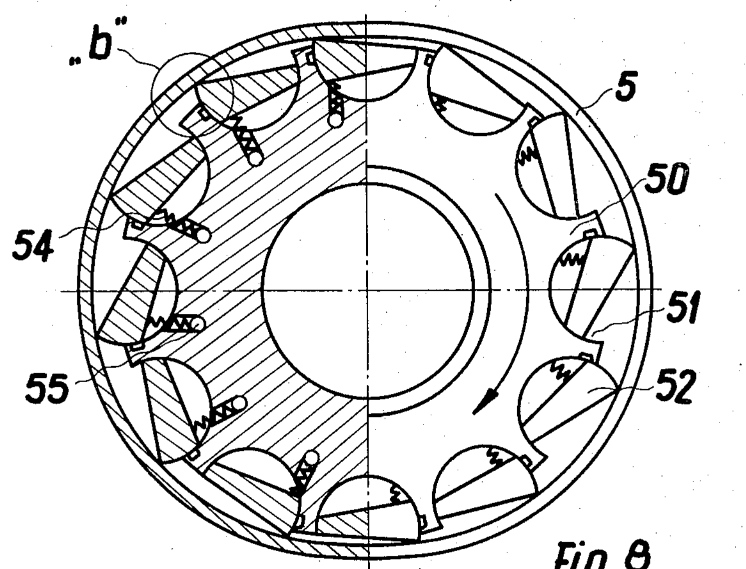


Fig. 8

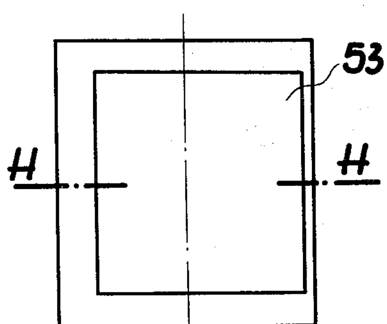


Fig. 9

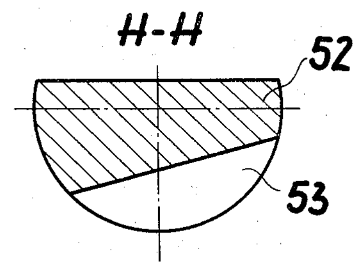


Fig. 10

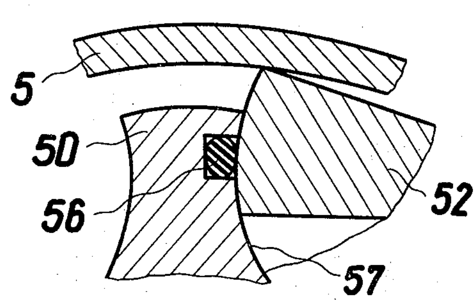


Fig. 11

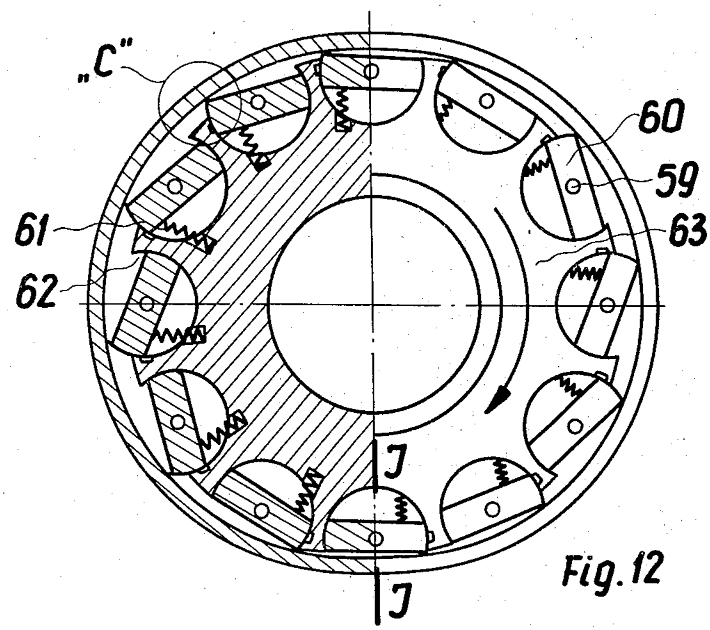


Fig. 12

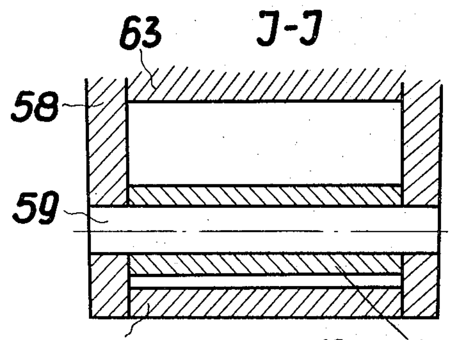


Fig. 13

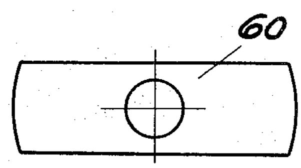


Fig. 14

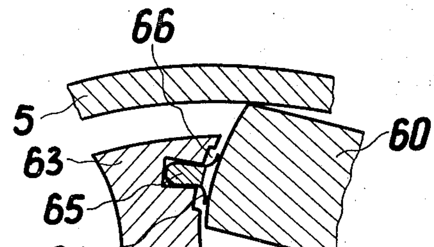


Fig. 15

VARIABLE-CAPACITY SLIDING-VANE PUMP

The invention relates to a variable-capacity double-acting sliding-vane pump which being driven by another pump becomes an engine of variable torque.

Particularly the invention relates to a pump having a cylinder provided with an oval hole and a cylindrical rotor in which pendulous vanes are mounted, sliding over the bearing surface in course of rotation of the rotor. Said cylinder is arranged inside a housing and can be of rigid or flexible construction. In a flexible cylinder its hole forming the bearing surface for the vanes is during the operation of the pump purposely deformed into an oval shape in order to achieve the pump capacity as desired.

The invention relates also to the design of vanes being employed in the pump into consideration, and to sealing them against the rotor and the cylinder.

The arrangement according to the invention can operate as a pump or a compressor if driven by a motor or engine, and also as an engine having variable torque if driven with a liquid medium pumped by another pump.

Known sliding-vane pumps are single-acting or double-acting ones provided with rotors having plate vanes slidably pushed out, or vanes mounted rotationally on a shaft fitted in the rotor. Of most frequent occurence there are pumps in which the rotor rotates in a cylinder forming simultaneaously the case, or in a cylinder constituting a separate part within the case. During rotation of the rotor, the vanes mounted in it slide over the bearing surface of the cylinder, forcing the liquid from the suction to the delivery chamber.

Owing to difficulties concerning the change of the rotational speed of the rotor during the operation of the pump, adjusting of the capacity of the pump is usually performed by means of to vary the volumes of the suction and the delivery chambers, whereby the speed of the rotor is maintained at constant value.

In single-acting sliding-vane pumps the capacity is controlled by adjusting the eccentricity of the rotor against the cylinder. The change of the eccentricity causes a change of volumes of the suction and delivery chambers.

Double-acting sliding-vane pumps have an oval cylinder of rigid construction, or flexible one admitting to shape it in an oval form.

Double-acting sliding-vane pumps with rigid cylinders enable to adjust the pump capacity by turning oval holes arranged on both sides of the cylinder axis, what causes the variation of the size of suction and of delivery chambers.

In pumps provided with flexible cylinders the adjusting of the pump capacity is performed by decreasing or increasing the ovality of the cylinder bearing surface.

In both single-acting and double-acting pumps vanes are known mounted rotationally on a shaft mounted on both sides in the rotor, or vanes mounted pendulously directly in channels made in the rotor. Said channels have their cross section shaped as a semi-circle or a polygone formed by several circular arcs.

The sealing of the vanes in the channels of the rotor is realized by strict fitting the bearing surface of the vane with that of the rotor.

Another method of sealing consists in providing the vane bearing surfaces with sealing straps being fixed durably.

Sealing of the pendulous vanes and single or double plate vanes guided in a groove of the rotor, against the cylinder bearing surface is most frequently performed by sharpening the vane edge sliding over the bearing surface. These vanes are pushed out from the inside by the pressure of liquid, spring, or centrifugal force.

A disadvantage of known single-acting sliding-vane pumps, in which the rotor is assembled eccentrically in realtion to the cylinder, is the high loading of the rotor bearings. Said loadings are considerable ones even at not high liquid pressures, thus the working pressures for the pumps of said type commonly do not exceed 35 kg./sq.cm. This is the cause that for higher pressures double-acting pumps are employed.

Fundamental disadvantage of double-acting pumps with variable capacity is their complicated structure being a cause that said pumps are not more widely employed in the practice.

Adjusting the capacity of a double-acting sliding-vane pump by means of turning the oval holes arranged on both sides of the rotor demands a rather complicated design of the side covers bearing said holes. Controlling of said covers is also rather inconvenient.

The structure of a sliding-vane pump with flexible cylinder is a complicated one, as it comprises numerous pistons and accompanying control members, wnaufacturing of which and assembling are exceptionally difficult.

Known pump rotors have their channels for mounting the vanes, having the rim angle smaller than 180°. Thus there exists a possibility of coming-out of the vane from the channel and of wedging the rotor in the pump cylinder, what makes necessary to provide additional safety devices.

The plate vanes, up to date most frequently employed in the practice, show an essential disadvantage consisting in high loadings on the edges of guide channels. Said disadvantage limits the range of working pressures.

Pendulous vanes mounted on comb hinges are suitable for to operate in pumps, they cannot be however employed in compressors owing to enormous volumetric losses caused by only partial draining off of the medium from chambers enclosed between the vanes. The comb-type hinging of the vanes when applied in compressors renders it superfluously difficult to make hinges of complicated form.

Sealing of the vanes on fixed surfaces precisely fitted with the rotor surfaces, or employing straps on vane bearing surfaces is effective as long as the arrangement is new. Following the wear and tear of rubbing surfaces the operation of the device gets worse. Replacing of vanes, necessary in such cases, is expensive, and replacing of straps fixedly fastened to the vanes is troublesome.

Sealing of the vanes in their contact area with the cylinder bearing surface by sharpening their edges does not give expected effects, as it is very difficult to keep the parallelity of said edge to the cylinder of the pump. The lack of parallelity results from inaccuracy of both machining and assembling. Employing of plates pushed out from the channels by spring or compressed liquid causes a need of to seal additionally the plates themselves against the rotor.

The object of the invention is to eliminate the inconveniences and disadvantages of known sliding-vane pumps through reducing the complexity of the pump design, simplifying its servicing, and increasing the efficiency of the pump.

Said object is achieved by providing new designs of the pump or its separate components, which will be subsequently described hereinbelow.

The invention consists in that in the known double-acting sliding-vane pump provided with rotary cylinder having oval race way there are employed as a new element, self-aligning vanes mounted on comb hinges, such a design ensures better distribution of forces on the vanes hinges. During the pump's operation the vanes are pressed down to the race way by means of centrifugal force and spring or only by means of centrifugal force.

The sliding-vane pump according to a modification is provided with an immovable cylinder but a rotary cross mounted on a control sleeve, turning of which causes a change of positioning of the suction and delivery chambers enclosed between the cylinder bearing surface and the recesses of the cross. The change of positioning of the chambers in relation to the oval hole of the cylinder causes the change of the pump capacity, and at larger displacement — the change of the flow direction of the medium. The cross is turned by means of a lever fastened to it.

The liquid inlet and outlet openings are made in the pump housing. The pump capacity is adjusted also at constant rotor speed. The maximum capacity of the pump can be obtained at positioning the arms of the cross at an angle of 45° to the axis of outlet and inlet openings. Whereas when the cross's arms coincide with the inlets and outlets — then the capacity is equal to zero.

In a sliding-vane pump according to another modification the bearing surface is formed by the inner surfaces of pistons which are connected between each other by flexible elements. The elements constituting the continuity of the bearing surface admit the liquid to flow through openings being provided therein.

Deformation of the flexible elements, thus change of the shape of the bearing surface, is realized by the displacements of the pistons which being controlled in pairs narrow the bearing surface in one direction wherethrough it gets extended perpendicularly to the direction of contracting. Controlling of the pistons may be performed continuously by hydraulic, pneumatic, or mechanical means, in course of rotations of the rotor.

The pump according to the present invention involves also new-type sealing of vanes both against the cylinder bearing surface and the rotor bearing surface.

From the side of the cylinder bearing surface each vane is provided with a pack of plates located loosely in a channel cut near to the edge of the vane. Said plates are forced out towards outside by an insert made of elastic material. Each plate of the pack is pushed out independently.

Most preferably the midpoint of the thickness of the plate pack, adjoining the cylinder bearing surface, covers with the point of intersection with the extended curvature line of the vane bearing surface.

The displacement of the plates towards outside is limited by the cylinder bearing surface. Supporting of the plate pack on the elastic insert admits each plate to be pressed down to the bearing surface, independently on the angle measured along the generating line of the vane in relation to the cylinder bearing surface. The plate pack contacting with the cylinder bearing surface forms a sort of labyrinth seal.

The vane with sealing plates arranged herein is pushed towards the cylinder bearing surface by centrifugal force or by spring.

The present invention involves also a modification of the rotor design according to which the rotor has on its periphery longitudinal channels having semi-circular cross section of a rim angle exceeding 180°.

In the rotor bearing surface an at least one longitudinal groove is cut, in which a rod-shaped seal is placed. The length of said seal equals approximately to the half of the vane length.

In order to improve the sealing effect an identical or similar seal is to be placed on the opposite side of the channel. The cross dimension of the seal is greater than the depth of the channel. Owing to elastic performance of the material, from which the seal is made, the seal changes its cross dimension as the vane bearing surface is pushed towards or away from the rotor bearing surface. Thus its contact with surfaces to be sealed is always secured.

To the shape of the channel the shape of vanes is matched, which in this case have a form of a cylinder planed on one side along the entire length. The vanes are also provided with recesses for to arrange therein the springs pressing down the vane to the cylinder bearing surface and to generate the pressure difference beyond and under the vane, wherefore the rotor is provided with according holes.

The rotor according to the second modification differs from the former by a groove cut in the rotor surface. In the groove there is located and fixed a thin-walled seal with arms spread in an Y-shape. The ends of the seal spread outwards are in contact with the vane bearing surface and seal it in both directions. At the outlet of the groove and parallely to it recesses are made in the rotor, into which come the spread ends of the seal at according thrust of the vane.

Said recesses secure the seal against squeezing in the clearance between the rotor and the vanes.

The vanes are in this design shaped as a cylinder planed on two sides of the entire length and are rotatively and concentrically born on the shaft. The shaft is with its ends born in side rings. Said shaft carries only a part of the loading of the vane, since the fundamental loading, affected by the liquid pressure, is carried by the rotor bearing surface.

In comparison with known designs, the designs of sliding-vane double-acting, thus relieved, pumps are little complicated, wherethrough the manufacturing and exploiting of them are easy and not expensive.

Mounting of the vanes on comb hinges increases the strength of the shaft.

By introducing of new designs of the rotor and seals a possibility is achieved of good internal sealing, thus the volumetric efficiency of the machine gets increased. The employed seals are easily exchangeable and simple in manufacturing.

There exists a possibility of to combine the designs from separate modifications of the cylinder, vanes, and seals.

The invention will be described on exemplary embodiments with reference to the accompanying drawings, in which:

FIG. 1 shows in its left-hand half the sectional view A—A after FIG. 2, and the right-hand half is the sectional view B—B after FIG. 2,

FIG. 2 is the cross-sectional view according to the line C—C in FIG. 1,

FIG. 3 shows in its left-hand half the sectional view E—E after FIG. 4, whereby the right hand half is the view of the pump,

FIG. 4 is the cross-sectional view along the line D—D of FIG. 3,

FIG. 5 shows in its left-hand half the view of the pump, the right-hand half being the sectional view F—F after FIG. 6,

FIG. 6 is the cross-sectional view of the pump along the line G—G of FIG. 5,

FIG. 7 shows the detail of execution "Q" from FIG. 1,

FIG. 8 is the half section of the rotor having vanes in form of a cylinder with planed sides,

FIG. 9 is the top view of the vane,

FIG. 10 is the sectional view of the vane along the line H—H after FIG. 9,

FIG. 11 shows the detail "*b*" of the rotor with vanes according to the FIG. 8,

FIG. 12 is the half section of the modification of rotor and vanes,

FIG. 13 is the sectional view along the line J—J after FIG. 12,

FIG. 14 is the side view of the vane,

FIG. 15 shows the constructional detail "*c*" of the rotor with vanes after FIG. 12.

Hereinbelow, the exemplary embodiments of separate modifications of pumps, rotors, vanes, and seals are described.

In the housing **1** the rotor **2** is arranged with vanes mounted on comb hinges and on axes **4**, and the cylinder **5** with external toothing.

The cylinder **5** is on its periphery guided by four offsets **6** of the housing **1**, and is on both sides closed by covers **7** screwed to the housing **1**. The inside of the cylinder **5**, having in FIG. 1 an oval shape, forms the bearing surface **8**, over which the vanes **3** slide during rotations of the rotor.

The space enclosed between the bearing surface **8** of the cylinder **5** and the rotor **2** and the covers **7** is in positions of four protrusions **9** sealed between adjacent vanes **3** with seal **10**. Said spaced communicate beyond the protrusions **9** with eight chambers, four of which are the suction chambers **11**, and the remaining four are delivery chambers **12**. The medium being pumped is supplied to the four suction chambers **11** through four openings **13**, and drained from delivery chambers **12** through four openings **14**.

Rotation of the rotor **2** born in sleeves **15** and provided with the seal **16** provokes the suction and delivery of the medium respectively, through openings **13** and **14** in the direction marked by full arrows in FIG. **1**.

By means of the toothed wheel **17** mounted on the pin **18**, as result of turning the crank **19** occurs the change of positioning of the cylinder **5**. At setting the longer axis of the oval of the bearing surface **8** at an angle of 45° to the axis of the protrusions **9**, the pump capacity equals to zero. Deflection of the bearing surface axis from said positioning to the left or right causes a constant increase of the pump capacity from zero to maximum, which is achieved when the oval axis covers with that of protrusions **9** on the cover **7**.

At defelection to the right by 45° from the zero position the maximum capacity is achieved and direction of flow shown by full arrows. At deflection to the left by 45° from the zero position the maximum capacity is achieved and the direction of flow shown by broken arrows.

The spring **20** causing the pressing down of the vane **3** to the bearing surface **8** is of particular significance when the unit according to the invention is employed as a hydraulic engine.

In the pump according to the modification of FIGS. **3** and **4**, the rotor **2** with vanes **3** and shafts **4** are made identically as in preceding example, only the structure of the cylinder and the method of controlling the direction of flow and of adjusting the capacity differ.

The crosses **21**, guided in the housing **22**, are provided with splines **23** engaging with the splines of the control sleeve **24**. In the sleeve **24** a sliding sleeve **25** is located. The housing is on both sides closed with covers **26** fastened to the housing by means of threaded rings **27**.

By means of the lever **28** fitted to the control sleeve **24** the positioning of the suction **30** or **31** delivery chambers is changed in relation to the oval of the bearing surface **29** formed in the housing **22**. Four suction chambers and four delivery chambers are formed by the arms **32** of the cross **21**.

The scale **33** indicates the value of the pump capacity being set up, as well as the direction of flow of the liquid through the pump.

In the pump according to the second modification of FIGS. **5** and **6**, the rotor **2** together with the vanes **3** and shafts **4** are made identically as in preceding examples, the design of the cylinder **34** and of the housing **41** is, however, different. Also the method of controlling the directions of flow and of adjusting the capacity are others.

The cylinder **34** according to this modification has thin flexible walls and is made as a single whole piece with four guiding pistons **35** and **36**. Said pistons are situated oppositely to each other, along axes perpendicular to each other.

Such a cylinder, formed by flexible elements and pistons, on its internal side has the bearing surface **37**, over which the rotor vanes slide. The form of the bearing surface changes from the circular one at zero position, that is according to the right-hand half of the FIG. **5**, to the position **38** or **39** on the left-hand half. The displacement along the main axes of the cylinder is actuated by motions of the pistons **35** and **36**.

The movements of the pistons **36** towards the centre and accompanying movement of the pistons **35** from the centre away form the shape of the bearing surface as **38**. The inverse movements of pistons form the shape of the bearing surface as **39**. The displacements of the pistons are controlled hydraulically, by utilizing of four openings **40** in the cover **41**. The housing in this modification is the same as in previous examples.

The change of the shape of the bearing surface corresponds with a change of the pump capacity, and of direction of flow of the liquid.

The rotor with vanes is on both sides closed with covers **42** fastened to the housing **41** with nuts **43**, and rotates as in previous modifications.

The flow of the liquid out of or into intervane spaces occurs through openings **44** into or from four chambers **45.**

The exemplary sealing of the vane, according to the invention is shown in FIG. 7 showing the constructional detail "Q" after FIG. **1.**

The pendulous vane **3** is mounted on the shaft **4,** which is born in combs of the rotor. At the edge **46** a channel is cut out, having rectangular cross section, as long as the vane. In this channel a pack of four plates **47** is put. Owing to the loose fitting, said plates can freely move in relation to each other, accordingly to the contact of the plates with the bearing surface. According to the example, the plates are made of steel but can also be made of other material.

At the bottom of the channel, under the plates **47** a rubber insert **48** is arranged. The rubber or other material having similar elastic properties behaves like a fluid, transmitting almost equal thrusts on each plate of the inserted pack. The thrust of the rubber insert and pressure of the spring or of the centrifugal force on the vane assures the requested pressing down of the plates to the bearing surface **8, 29,** or **37** of the cylinder.

An exemplary design of the rotor with vanes and their seals, applied in the pump, is described hereinbelow and in FIGS. **8** to **11.**

In the cylinder of the variable-capacity double-acting pump the rotor **50** is arranged. Said rotor is provided with twelve channels **51** having a semi-circular cross section, being cut out on its periphery. In these channels vanes **52** are placed.

The vanes have a form of a cylinder planed on one side of the entire length. The diameter of this cylinder is fitted with the diameter of the channel, what renders possible that the vane performs rotary motion in the channel in course of rotation of the cylindrical rotor within the oval cylinder. In order to secure the vane against being pushed out of the channel, the rim angle of the channel **51** exceeds 180°. From the side of the rotor the vane is provided with the recesses **53** in which four springs **54** are placed pressing down the vanes to the bearing surface. Besides the pressure of springs, the vane is pressed to the bearing surface by the pressure difference, generated by the supply and draining respectively the liquid from below the vane through the openings **55.**

On one wall of each channel of the rotor **50** a rectangular groove is cut out, reaching over the entire length of the rotor. In said groove a rubber round seal **56** is placed. The diameter of the seal is greater as the depth of the groove but smaller than its width. Owing to the difference the seal remain in permanent contact with the vane. The length of the seal equals to the length of the rotor and the vane.

The rotor according to the modification in FIGS. **12** to **15** is on both sides provided with side rings **58** coupled with the rotor, performing rotary motions together with the rotor. In said rings shafts **59** are born, on which vanes **60** are mounted rotatively. Said vanes are made in form of a cylinder planed on the entire length on two sides. The pressure of the vanes down to the bearing surface is realized by means of four springs **61.**

The channels **62** of the rotor **63** has a groove having its length equal to the length of the rotor, being cut out in one of walls. In this dovetail-shaped groove the seal **64** is placed, made of flexible sheet metal, being deflected on two sides, thus having a shape of the letter Y. Said seal is secured against falling out of the groove by means of the wedge **65.** The seal abuts on the vane with both spread ends, thus a two-directional tightness is secured.

In order to prevent the seal to be squeezed in the clearance between the vane and the rotor, just at the groove cut out in the rotor, two suitable recesses **66** are provided.

What we claim is:

1. Variable-capacity double-acting sliding-vane pump which being driven by means of another pump becomes an engine of variable torque, consisting of a housing enclosing a cylinder arranged therein, and a rotor with vanes mounted therein, which vanes slide over the bearing surfaces of the cylinder as the rotor rotates, said vanes being self-aligning and sealed by means of a plate pack placed loosely in a channel cut out in each vane and pushed outwards by an insert made of an elastic material, the channel for the plates being cut out near the edge of the vane, the center of the thickness of the plate pack, remaining in contact with the bearing surface, lying in the point of intersection of the extended line of the curvature of the vane bearing surface with the cylinder bearing surface.

2. The pump of claim **1,** in which the vanes are mounted on the rotor by means of comb hinges.

3. The pump of claim **2** including movable crosses with arms mounted rotatively on a control sleeve, and connected with a lever for changing the positions of suction chambers and delivery chambers.

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