Dec. 13, 1949

A. ZEITLIN

2,491,352

ROTARY PUMP

Filed Sept. 26, 1944

2 Sheets-Sheet 1

Fig. 1.

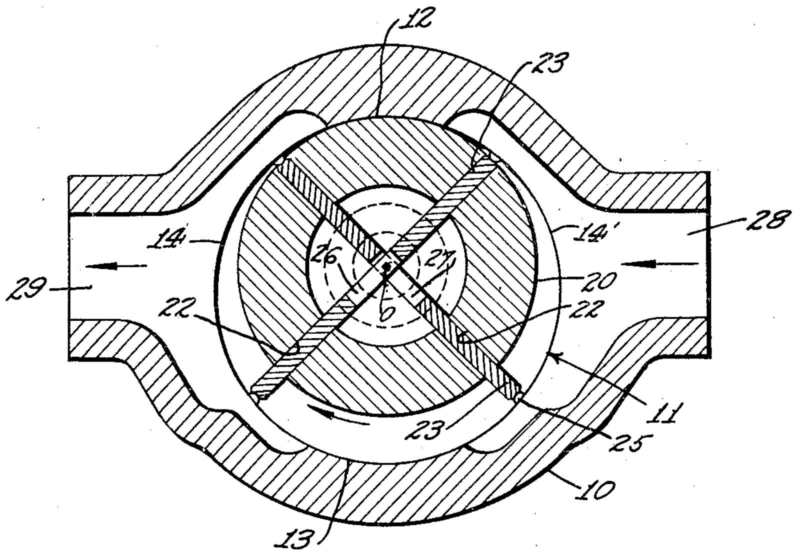
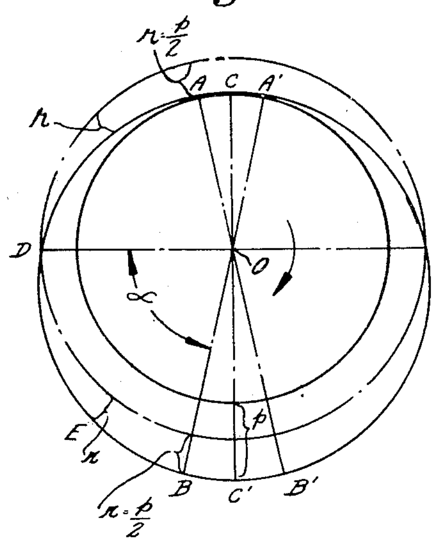


Fig. 2.



INVENTOR.
ALEXANDER ZEITLIN
BY
Joseph H. Lipschutz
ATTORNEY

Dec. 13, 1949

A. ZEITLIN

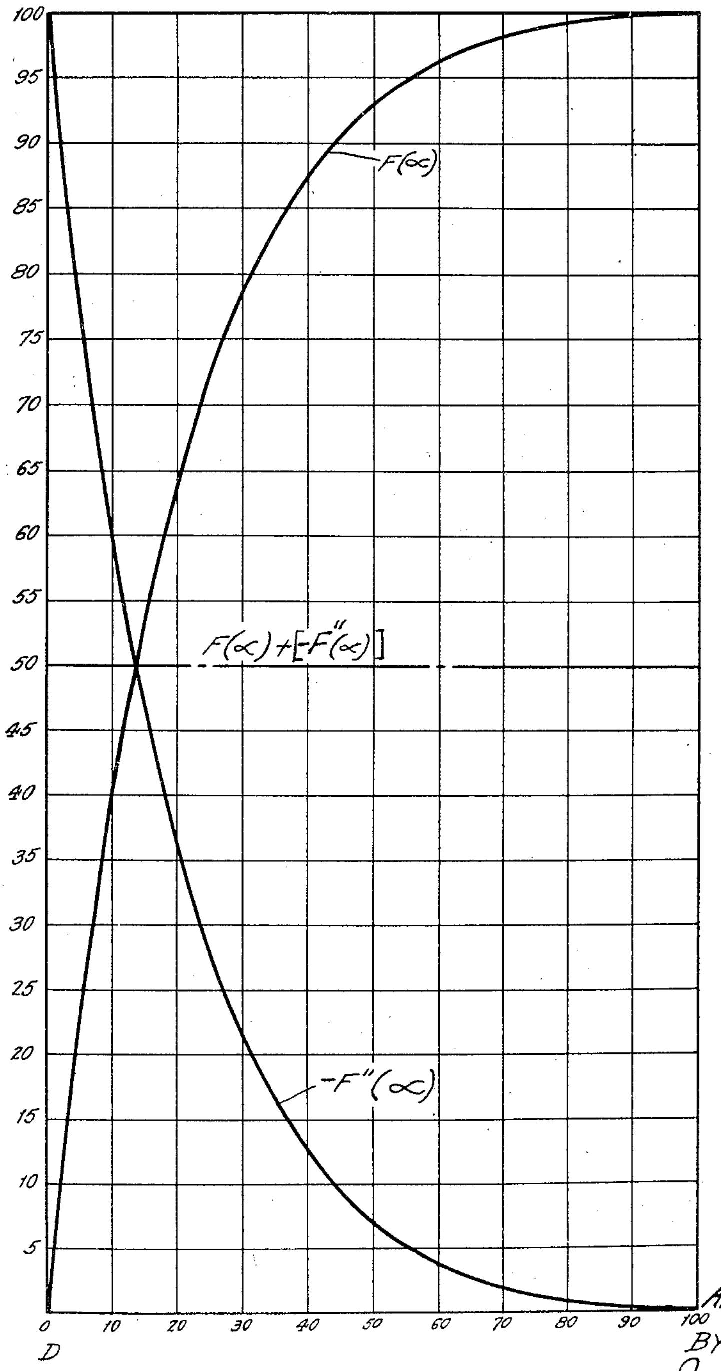
2,491,352

ROTARY PUMP

Filed Sept. 26, 1944

2 Sheets-Sheet 2

Fig. 3.



INVENTOR.
ALEXANDER ZEITLIN
BY
Joseph H. Lipschitz
ATTORNEY

Patented Dec. 13, 1949 2,491,352

UNITED STATES PATENT OFFICE

2,491,352

ROTARY PUMP

Alexander Zeitlin, New York, N. Y.

Application September 26, 1944, Serial No. 555,803

2 Claims. (Cl. 103—138)

1

This invention relates to rotary pumps or compressors of the sliding-vane type. In these pumps the rotor rotates about an axis within an eccentric bore and carries the sliding vanes which are at all times in engagement with the walls of the bore. The bore is so formed that its curvature causes the vanes to be alternately retracted and extended during each revolution of the rotor.

It has been found that certain sections of the bore are subjected to greater pressures than other sections and furthermore that in the sections of greatest pressure excessive wear occurs unevenly throughout the length of the section. This sets up vibrations and uneven discharge of the fluid in addition to causing excessive wear on the bore.

It is one of the principal objects of this invention to provide in a pump of the type described a bore which will not wear excessively, but which will wear evenly and thus not set up vibrations but will rather produce even, substantially pulsationless flow throughout the life of the pump.

Further objects and advantages of this invention will become apparent in the following detailed description thereof.

In the accompanying drawings,

Fig. 1 is a cross-section through a rotary pump of the sliding-vane type.

Fig. 2 is a diagrammatic representation of the bore illustrating the principles of this invention.

Fig. 3 is a graphic method of laying out the curvature of the bore in accordance with the principles of my invention.

Referring to Fig. 1 of the drawings there is shown a body **10** of a rotary pump casing having a bore **11** which is formed of two diametrically opposed circular arcs **12** and **13** of different radii from a common center O, connected by curves **14**, **14'** of special design to be more fully described hereinafter. The rotor **20** is mounted for rotation about axis O and is of substantially the same radius as circular section **12** against which it bears. The rotor is provided with transverse diametric slots **22** within which operate vanes **23** of a length equal to the sum of the radii of circular sections **12** and **13**. The vanes may be provided with bearing elements in the form of rockers **25** at their outer ends bearing on the inner surface of the cylinder bore. It will be understood in the following description that references to the length of vanes includes the radial projections of the rockers, and it will be further understood that the necessary clearances are employed; also the terms "pump" and "compressor" are used interchangeably. The vanes are provided with intermediate cutout portions **26**, **27** to enable them to clear each other. Inlet and outlet ports **28** and **29** are provided.

Except for the special design of connecting curves **14**, **14'**, the above description covers the

2

familiar elements of the rotary vane type pump or compressor. It is apparent that as the rotor rotates, the ends of the vanes at one side are forced into the rotor, while those at the other side are forced out of the rotor. The vanes forced out of the rotor form with the cylinder bore an expanding chamber for drawing fluid into the pump, while the vanes forced into the rotor constitute the discharge or pressure side by reason of a continuously decreasing chamber. In the case of an incompressible fluid such as a liquid, the inlet and outlet ports are co-extensive with the connecting curves **14**, **14'**, but in the case of compressible fluids such as air or gas, the inlet and outlet ports may be of lesser length than the connecting curves.

It will be seen by reference to Fig. 1 that when the vanes are in a position symmetrical with respect to the rotor, they project equally from each side of the rotor. In this position, and in this position only, the radius vector OD is equal to the radius vector OD'. The radius vector is the straight line distance from the center of rotation O to the wall of the bore. It will be seen that in the portion of the bore from point D to point A the radius vectors will be less than OD and in the portion of the bore from D to B the radius vectors will be greater than OD. The difference between OD and the radius vectors to other points of the bore may be indicated by r, and it will be apparent that the value of r is a function of the angle α measured from the base line DOD'. If the total difference in length between the vane and the diameter of the rotor is indicated by p, then at points A and B the value of r will be

$$\frac{p}{2}$$

The pressures which are exerted on the wall of the bore are not the same throughout the bore. This will become apparent from a study of the diagram in Fig. 2 wherein it is seen that during certain portions of a revolution of the rotor the vanes are being pushed into the rotor by the bore, thus exerting a strong reaction pressure on that portion of the bore, while in the opposite portions of the bore the vane is being extended from the rotor, thus exerting substantially little reaction pressure on that section of the bore. Also, during certain portions of the revolution of the rotor the vanes are exerting centrifugal force against certain portions of the bore, while in other portions of the bore such force is not being exerted. Thus, for example, assuming clockwise rotation of the rotor, in the portion of the bore BDA the curvature of the bore is such as to force the vanes into the rotor and thus the entire reaction pressure caused by acceleration of the vanes diametrically through the rotor is taken up by this section of the bore.

The sections of the bore A' D' B' however do not have to impart such acceleration to the vanes since the vanes are moving outwardly of the rotor. Furthermore, it will be noted that the center of gravity of each vane is at or below the base-line DOD' at all times. Therefore, the portions of the bore D' B' and BD are subjected to the centrifugal force of the vanes. From this discussion it becomes apparent that there is one section of the bore, i. e. BD, which is subjected to both the acceleration force incident to imparting radial acceleration to the vanes and the centrifugal force of the vanes. It becomes apparent, therefore, that this section of the bore is critical because it is subjected to the maximum amount of pressure, and it is this section which heretofore developed unevenness which caused vibration, variations in discharge and rapid wear.

I have found that the remedy for the above conditions resides in causing the sum total of the pressures acting upon the bore to be substantially constant throughout the angular movement of the vanes and thereby unevenness of wear, with consequent rapid deterioration and vibration, is avoided. In order to accomplish this result I so design the curvature of the bore that the sum total of the acceleration force of the vane radially of the rotor and the centrifugal force of the vanes will always be constant. In order to design such curve, the following consideration governs. By reference to Fig. 2 it will be seen that the centrifugal force will depend upon the distance of the center of gravity of the vane from the axis of rotation. This distance is equal to the value of r which is the amount by which the vane projection varies from its projection in the symmetrical position or base-line DOD' in which position the center of gravity of the vane coincides with the axis of rotation O. Further, we have seen that the value of r is a function of the angle of a radius vector drawn from the axis of rotation and measured from the base-line. Therefore it may be stated that the pressure due to centrifugal force is equal to r multiplied by a constant or

$$P_{cf}=K\cdot r=K\cdot F(\alpha)$$

where K is a constant depending upon the R. P. M., the mass of the vane and other constant factors, and F stands for "function of"

The pressure due to the radial movement of the vane is proportional to the acceleration in a radial direction, or expressed mathematically is

$$P_{ac}=K\cdot\left(-\frac{d^2r}{d\alpha^2}\right)=K\cdot[-F''(\alpha)]$$

where F'' stands for "the second differential of the function of."

The total pressure exerted on the section of the bore DB is therefore

$$P=K\cdot r+K\left(-\frac{d^2r}{d\alpha^2}\right)$$
$$=K\cdot F(\alpha)+K\cdot[-F''(\alpha)]$$

In order therefore to achieve the desirable results which I have set forth hereinbefore, the bore must be a curve in which

$$P_{cf}+P_{ac}=\text{a constant}$$

i. e.,

$$F(\alpha)+[-F''(\alpha)]=\text{ a constant}$$

There are different methods by which a curve satisfying these conditions may be laid out. Thus, an equation may be devised in the form of a

power series, or a logarithmic, exponential or trigonometric equation. Another method is the graphic method, and the principles of design by the graphic method are well-known. I have employed the graphic method herein as an example, as shown in Fig. 3, in laying out the portion DB of the bore. Fig. 3 represents a development of a curve wherein it will be seen that the sum of the $F(\alpha)$ and $[-F''(\alpha)]$ at every point equals a constant. Similarly the portion DA of the bore may be graphically designed, and since the bore is symmetrical, and in any case since the pump is reversible, the curvature of the section A' D' B' will be the same as that of ADB.

The same formulas are used for arcs DA, D'A' as for the arcs DB, D'B' except that for the arcs DB and D'B' the value of r is added to the basic circle, whereas in arcs DA and D'A' the value of r is deducted. Consequently, for each diameter, the value of r is added at one end and subtracted at the other end. It is obvious that the length of the diameter thus remains constant in all positions, and since the vane has the length of this constant diameter it will engage the bore at both ends in all positions.

The following is a table of values of

$$\text{"\% of }\frac{p}{2}\text{"}$$

relative to "% of angle α_1" worked out by the graphic design method, wherein α_1 is the value of α between the base-line DOD' and point B:

Graphically designed curve for which $F(\alpha)+[-F''(\alpha)]$ is substantially constant

α in % of α_1	$r=F(\alpha)$ in % of $\frac{p}{2}$	α in % of α_1	$r=F(\alpha)$ in % of $\frac{p}{2}$
0	0.00	51	93.50
1	5.00	52	93.90
2	9.75	53	94.25
3	14.25	54	94.60
4	18.55	55	94.90
5	22.60	56	95.20
6	26.45	57	95.50
7	30.10	58	95.75
8	33.60	59	96.00
9	36.90	60	96.25
10	40.05	61	96.65
11	43.05	62	96.70
12	45.95	63	96.90
13	48.65	64	97.10
14	51.25	65	97.30
15	53.70	66	97.50
16	56.05	67	97.65
17	58.25	68	97.80
18	60.35	69	97.85
19	62.35	70	98.10
20	64.25	71	98.25
21	66.05	72	98.40
22	67.75	73	98.55
23	69.35	74	98.70
24	70.85	75	98.80
25	72.30	76	98.90
26	73.65	77	99.00
27	74.95	78	99.10
28	76.20	79	99.20
29	77.40	80	99.30
30	78.55	81	99.40
31	79.65	82	99.45
32	80.70	83	99.55
33	81.70	84	99.60
34	82.70	85	99.65
35	83.65	86	99.70
36	84.55	87	99.75
37	85.40	88	99.75
38	86.20	89	99.80
39	86.95	90	99.80
40	87.65	91	99.85
41	88.35	92	99.85
42	89.00	93	99.90
43	89.60	94	99.90
44	90.15	95	99.95
45	90.70	96	99.95
46	91.20	97	99.95
47	91.70	98	100.00
48	92.20	99	100.00
49	92.65	$100=\alpha_1$	100.00
50	93.10		

In accordance with the provisions of the patent statutes, I have herein described the principle and operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other equivalent means. Also, while it is designed to use the various features and elements in the combination and relations described, some of these may be altered and others omitted without interfering with the more general results outlined, and the invention extends to such use.

Having described my invention, what I claim and desire to secure by Letters Patent is:

1. In a rotary pump or compressor having a body, a cylindrical rotor therein, said body having a bore eccentric with respect to the rotor, said rotor having radial slots and vanes slidable in said slots, the length of said vanes being greater than the diameter of the rotor, said vanes being adapted to be in contact with the bore in all positions, the eccentricity of the bore operating to expand and retract the vanes, certain portions of the bore being subjected to the centrifugal force due to the rotation of the vanes and to the acceleration force due to the radial acceleration of the vanes in the rotor, characterized by means for reducing wear of said portions, said means comprising the curvature of the bore in said portions so formed that

$$K \cdot r + K\left(-\frac{d^2 r}{d\alpha^2}\right) =$$

substantially a constant for every position of the vanes on said portions, wherein

r represents the distance between the center of rotation and the center of gravity of the vanes.

α represents the angle between a base line where the vanes project equally at opposite sides of the rotor and a radius vector drawn from the axis of rotation of the rotor to a point on said portions of the bore.

2. In a rotary pump or compressor having a body, a cylindrical rotor therein, said body having a bore eccentric with respect to the rotor, said rotor having radial slots and vanes slidable in said slots, the length of said vanes being greater than the diameter of the rotor, said vanes being adapted to be in contact with the bore in all positions, the eccentricity of the bore operating to expand and retract the vanes, certain portions of the bore being subjected to the centrifugal force due to the rotation of the vanes and to the acceleration force due to the radial acceleration of the vanes in the rotor, characterized by means for reducing wear of said portions, said means comprising the curvature of the bore in said portions so formed that $F(\alpha) + [-F''(\alpha)]$=substantially a constant for every position of the vanes on said portions, wherein

F represents "function of."

α represents the angle between a base line where the vanes project equally at opposite sides of the rotor and a radius vector drawn from the axis of rotation of the rotor to a point on said portions of the bore, and being equal to $\mathbf{K} \cdot r$ where K is a constant depending upon the R. P. M., the mass of the vane and other constant factors, and r represents the distance between the center of rotation and the center of gravity of the vane.

F'' represents the second differential of r with respect to α.

ALEXANDER ZEITLIN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,165,963	Curtis	July 11, 1939

FOREIGN PATENTS

Number	Country	Date
206,582	Great Britain	Nov. 8, 1923