Oct. 10, 1944. B. E. FANNING 2,359,903

ROTARY PUMP OR MOTOR

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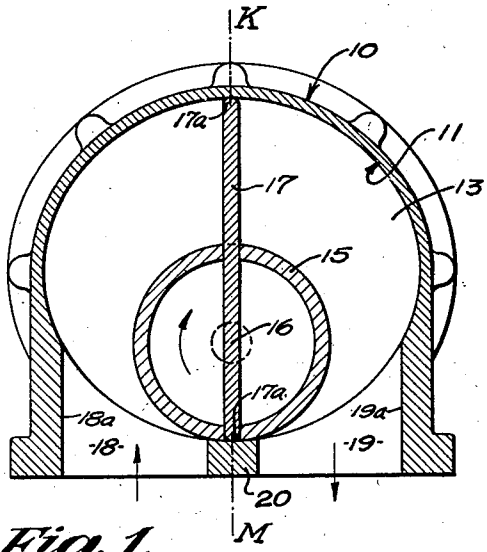

Fig. 1.

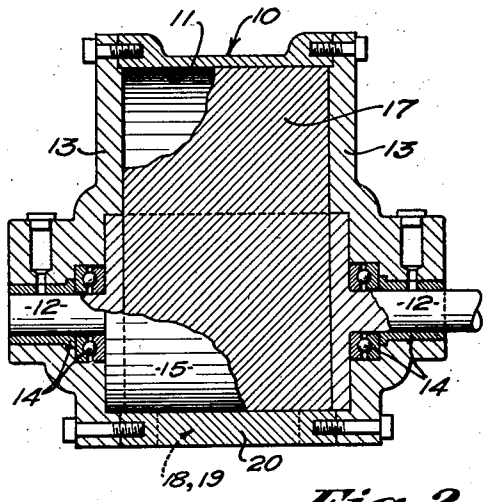

Fig. 2.

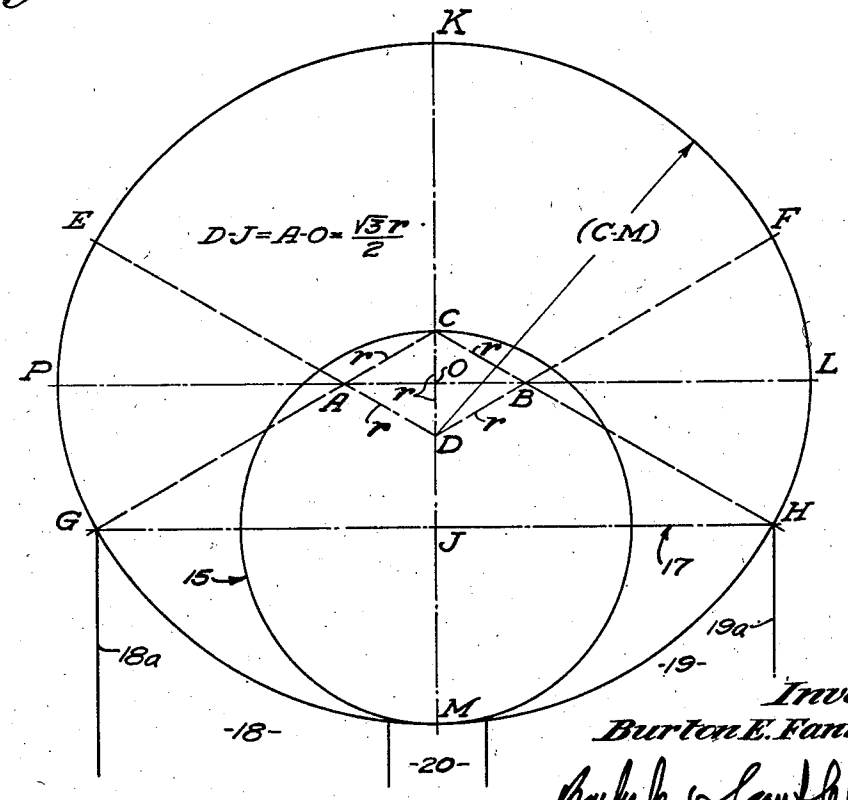

Fig. 3.

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ROTARY PUMP OR MOTOR

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3 Claims. (Cl. 103—137)

My invention has to do with hydraulic or fluid flow devices of a type which is characterized by a shuttle which rotates, within a suitably shaped cylinder, and rotates with and slides through an interior rotor on an axis eccentric of the cylinder. A device of that type may be used in many different kinds of fluid or hydraulic circulation systems, and may be used either as a pump, or as a motor, or as a measuring device or meter, or may be used in hydraulic power transmission systems. My developments and improvements in such devices have in view all of the various uses to which such devices may be put.

My invention has more particularly to do with the shape and contour of the cylinder surface with which the rotating sliding shuttle cooperates. Many attempts have evidently been made in the past to develop a fully satisfactory contour for that cylinder, but for one or more reasons all such attempts have failed to develop a fully satisfactory cylinder curve, both from the standpoint of initial lay-out and from the standpoint of ease and accuracy of physical formation by machining or grinding operations or the like. A large proportion of these prior attempts are typified in the following discussed prior patents.

In the type of cylinder curve described in the Williams and Fisher Patent 518,299, dated April 17, 1894, the relative dimensions of the internal rotor (diameter) and the length of its diametral shuttle or piston are, relatively, arbitrarily assumed. One arcuate face of the cylinder wall is then formed as the arc of a circle which is tangent to the rotor and also to the ends of the assumed shuttle when the shuttle is in a medial position in the rotor. The relative radius of this arc of course depends upon the relative assumptions which have been previously made with regard to the dimensions of the rotor and the shuttle. The remainder of the curved cylinder wall is then generated by the path of one end of the shuttle as the other shuttle end follows the circular path initially assumed. The result does not necessarily produce a true elliptic curve, or one which is symmetric about both major and minor axes.

In the type of cylinder curve shown in the patent to Balch 913,255, February 23, 1909, the cylinder curve is generated by constraining the center point of the shuttle to movement in a circle while the shuttle rotates with and slides in the internal rotor. The cylinder curve developed by this method is typically heart shaped, of irregular curvature, is symmetric only about one axis, and does not lend itself easily to accurate generation. Its irregularity of curvature, as well as its asymmetry causes the sliding shuttle to be given sharply varying accelerations during its rotation and hence leads to rapid wear of both the shuttle and the cylinder wall.

Symmetry of the cylinder curve about both major and minor axes is important not only from the standpoint of facility of design and practicability of formation, but also with regard to wear of the cylinder surface and the shuttle. In my cylinder design as will appear, the cylinder surface is elliptic, or very closely elliptic, and the sliding accelerations given to the shuttle are consequently of smoothly changing values.

The typical cylinder curve shown in the Gill Patent 899,040, September 22, 1908, also has the disadvantages of abrupt changes of curvature and non-symmetry. In the method of cylinder generation typified by Gill, two opposing circular arcs are first arbitrarily chosen, and the adjacent ends of those two circular arcs are then joined by two curves which may either be formed by generation from the shuttle, or are formed as involutes.

It is the general object of my present invention to provide a cylinder curve which is of smoothly changing curvature, without any abrupt changes of that curvature, which is substantially of elliptic formation and symmetric about both the major and minor axes, and which will maintain within allowable tolerances a sufficiently close fit with the sliding shuttle in all positions as to substantially eliminate fluid slip or leakage. In addition to the advantages which have already been mentioned as accompanying symmetry of the curve about both axes, I also note that that symmetry in my design makes it possible to operate the pump or motor or similar device in either direction of rotation without any change in the manner in which the device acts on the fluid or the fluid acts on the device. Thus, my improved device lends itself most readily to action under valvular control for reversing.

In the accompanying drawing and in the following specification, I show and describe a typical formation and structure of only a single element or unit involving my invention. This unit structure however may be used in any type of system in which such devices are useful, in duplicate or multiple in any type of fluid circuit, either closed or open, and with the units arranged in series or multiple arrangement, or in series-multiple; and, as in a transmission system, one or more units may be the driver or pump which actuates the others which operate as motors or as meters.

In the accompanying drawing an illustrative structure is shown, but only by way of example to illustrate structure embodying the cylinder of the shape and configuration which my invention provides. In the drawing

Fig. 1 is a vertical cross section showing typical structure;

Fig. 2 is a central longitudinal section, and

Fig. 3 is a diagram illustrating the contour and

the method of construction of the cylinder curve.

In the drawing a suitable cylinder wall structure is designated generally by numeral 10, having an inner chamber bounded peripherally by the elliptically curved wall which is generally designated by the numeral 11. The length of the cylinder (its dimension parallel to the axis of rotor shaft 12) may be anything desired. Its contour as viewed endwise as in Fig. 1 is substantially elliptic, and symmetric about its major axis (horizontal in Fig. 1) and its minor axis (vertical in Fig. 1).

Suitable end plates or heads 13 close the cylinder ends and carry bearings 14 in which rotor shaft 12 is journalled. Rotor 15 may preferably be recessed at its ends into heads 13, and its axis of rotation, indicated by 16 in Fig. 1, is set in such a position on the minor axis of the elliptic cylinder wall that rotor 15 is tangent to the elliptic cylinder wall along a longitudinal line which line is the minor axis plane designated K—M in Fig. 1.

The shuttle piston 17 slides diametrally through rotor 15, which may either be solid or hollow as illustrated, and is of such dimension in an axial direction as to fit with the required snugness between end heads 13, and is of a length (dimension diametral of rotor 15) which is determined as hereinafter described.

Viewed as in Fig. 1, casing 10 is provided with two ports 18 and 19 in the relative locations illustrated, separated by the central wall 20, and arranged symmetrically with relation to the minor axis plane K—M. As will appear, either of these ports may function either as inlet or outlet port.

The characteristic novelty and the advantages of my invention reside in the shape and contour of the internal cylinder surface 11. The method by which curvature of this surface is laid out, and its characteristic relative dimensions, will now be described. As I have stated, this curvature is substantially elliptic, but it is one of the preferred characteristics of my invention that the curvature is made up of a series of circular arcs, each of which, both as to radial dimension and circumferential extent, are definitely determinable after one determining dimensional factor has once been chosen. Determination of that one dimensional factor determines at once all of the dimensions and curvatures of the cylinder surface as well as the diametral dimension of the rotor and the length of the shuttle. All those dimensions, as will appear, bear a definite relation to the initially determined dimension or unit, which latter may therefore be used wholly in comparing any number of different sizes of the same type of cylinder design.

The procedure for laying out the curvature for the cylinder surface, and the characteristic of that curved surface will now be described. With a selected dimensional unit, the rhombus A—C—B—D is first laid out, with its four sides and minor diagonal of the same dimension—the dimension r which has been selected as the unit. The rhombus, thus produced, has internal angles of 120° at C and D, and of 60° at A and B. The lines K—M and P—L represent the minor and major diagonals of the rhombus prolonged. Their intersection at O defines the center of the rhombus. The distance A—O is then laid out from D along K—M, defining the point J, which is the center of rotor 15 whose radius is drawn equal to J—C. The line G—H is then drawn through J perpendicular to K—M, and circular arc G—M—H is drawn about center C, tangent to the periphery of rotor 15 at M, and intersecting the line G—H at, and defining, the points G and H.

The sides of the rhombus are prolonged to the points G and H, and also to points E and F, as shown in the diagram. The arc E—K—F is drawn about a center at D and with radius equal to C—M. This arc, and arc G—M—H, are arcs of 120°, as they lie between radial lines which, by definition of the rhomboidal figure, include angles of 120°. The circular arcs E—P—G and F—L—H are then drawn, about centers A and B respectively. These arcs are each of 60° extent, as they lie between radial lines which are prolongations of the sides of the rhombus and which, by the definition of the rhomboidal figure, include angles of 60°. The completed closed curve is very closely elliptic; having a major axis P—L and a minor axis K—M. The circle 15 represents the determined size of the rotor, and the length of line G—H determines the linear length of shuttle 17.

Using the dimension r as a unit, the controlling and characteristic dimensions of the ellipse laid out are as follows:

A—O and D—J are equal to

$$(1) \qquad \sqrt{r^2-\left(\frac{r}{2}\right)^2}=\frac{\sqrt{3}r}{2}$$

The displacement of rotor center J from ellipse center O, along minor axis K—M, is the sum of O—D, and D—J,

$$(2) \qquad \frac{r}{2}+\frac{\sqrt{3}r}{2}=\frac{(1+\sqrt{3})r}{2}$$

The radius J—M or rotor 15 is

$$(3) \qquad r+\frac{\sqrt{3}r}{2}=\left(1+\frac{\sqrt{3}}{2}\right)r$$

The radii of arcs G—M—H and E—K—F are equal to the diameter of 15 and therefore

$$(4) \qquad (2+\sqrt{3})r$$

The radii of arcs E—P—G and F—L—H are equal to the last named dimension minus the quantity r and therefore,

$$(5) \qquad (1+\sqrt{3})r$$

And the length of G—H of shuttle 17 is

$$(6) \qquad (3+2\sqrt{3})r=6.464r$$

The semi-major diameter of the ellipse P—L, is

$$(7) \qquad \left(1+\frac{3}{2}\sqrt{3}\right)r=3.598r$$

The semi-minor diameter of the ellipse is

$$(8) \qquad \left(\frac{3}{2}+\sqrt{3}\right)r=3.232r$$

The ratio of minor to major diameter is

$$(9) \qquad \frac{\frac{3}{2}+\sqrt{3}}{1+\frac{3}{2}\sqrt{3}}=0.8983$$

And the ratio of the displacement of the rotor and shuttle center J from the ellipse center O, to the semi-minor diameter of the ellipse is

$$(10) \qquad \frac{1+\sqrt{3}}{3+2\sqrt{3}}=0.4226$$

The elliptic figure is of course symmetric about both its major and minor axes. And in this elliptic figure, constructed and proportioned as stated, all chords drawn through center J are very nearly equal. Those chords represent the linear length of shuttle 17 and, disregarding for

the moment the thickness of the shuttle, that fact provides that a shuttle of the determined length will, within allowable tolerances, contact the elliptic surface of the cylinder at both ends throughout its revolution. The shuttle 17 has to have some substantial thickness, and the curved formations 17*a* at its ends may be made such as to compensate for the thickness of the shuttle by providing end surfaces which will maintain linear engagement with the cylinder surface throughout the change in angle between the shuttle length and the cylinder surface which occurs during a revolution. The effective length of the shuttle is made such as to have a slight fitting clearance at the cylinder wall, that clearance being dictated by considerations of minimizing frictional resistances, minimizing fluid slip or leakage, and accommodating temperature changes.

In the elliptic cylinder figure as constructed, the total area of the ellipse is equal to $36.1214r^2$; and the effective fluid occupied area (the meniscus defined by the elliptic figure and the circle of rotor 15) is equal to $25.1822r^2$. The effective fluid occupied volume is also controlled by the dimension of the axial length of the cylinder; and if, for instance, that axial length bears a definite proportion to r, the effective fluid-occupied volume in devices of different sizes varies as r^3. In giving these comparative figures for areas and volumes the cross sectional area and volume of shuttle 17 is neglected.

The inlet, outlet openings 18, 19 preferably have their inner adjacent defining walls separated only by the narrow dividing wall or web 20, so that those adjacent defining walls are as close together, and as close to the elliptic minor axis K—M as is practicable. The two outer port defining walls 18*a* and 19*a*, are preferably coincident with the points G and H in the diagram. Consequently, shuttle 17 completely covers and closes both ports 18 and 19 only in one instantaneous shuttle position, the "medial" position shown in diagram in Fig. 3 where the shuttle center is coincident with rotor center J. Upon rotation from that medial position in either direction (say for instance rotation clockwise in Fig. 3) the right hand end of shuttle 17 begins to uncover the edge of port 19, just as the left hand end of the shuttle finally closes the edge of port 18. The fluid enclosed in the sector G—K—H above the shuttle thus immediately begins to move out through port 19 as the left hand end of the shuttle begins to move the otherwise enclosed volume of fluid around through that sector. The volumetric speed at which the fluid begins to move out through port 19 (at any given rotary speed of the device) is controlled by the relative areas of the shuttle which are exposed at its ends beyond the periphery of rotor 15. That relation changes as the shuttle approaches the position shown in Fig. 1, and the volumetric speed of fluid movement outwardly through port 19 and likewise inwardly through port 18 becoming gradually larger until the position of Fig. 1 is reached, when both fluid flows then gradually decrease until the shuttle position shown diagrammatically in Fig. 3 is again reached, the shuttle having rotated through 180°. Further rotation of the shuttle past the last mentioned position is then still moving fluid out through port 19 when the shuttle again begins to uncover port 19 just as port 18 is closed, to start a new 180° cycle of operation.

The fluid movement through a single unit of the device, assuming the rotor to be driven at constant rotary speed, is of course pulsative but with very smooth graduations of flow. Likewise, assuming an even volumetric flow of fluid through the device when operating as a motor or the like the rotation of the device is somewhat pulsative but with very smooth graduations. To smooth out the pulsations any desired number of the described units may be mounted in bank in a single structure or rotatively connected as by being mounted on a single shaft.

As I have previously stated, any desired number of the units may be utilized in any desired fluid flow system, for any of the purposes to which such a unit or bank of units is applicable. In any such system, control of the unit or units may be had by any suitable valvular control which may either be located at a distance in a circulating or control system, or which may be located immediately adjacent a unit or units, as by being located directly at the faces of ports 18 and 19. With suitable valvular control, the flow of fluid, and rotation of the device or devices may be reversed or stopped altogether and the fluid flow also may vary from zero to maximum for control and variation of speed.

I claim:

1. In a rotary fluid-flow device of the type described, having a cylinder, a diametrally slotted rotor eccentrically placed within the cylinder and tangentially contacting it, and a rotating-sliding shuttle carried in the rotor and contacting the cylinder at opposite shuttle-ends throughout its rotative movement; characterized by any cross-sectional form of the interior cylinder surface throughout its length being substantially elliptic, formed exclusively of circular cylindric arcs which mutually join each other tangentially, and symmetric about both major and minor axes, and the rotor center being offset from the elliptic center along the minor axis.

2. The device as defined in claim 1, further characterized by the ratio of elliptic minor to major diameter being approximately 0.8983, and the displacement of the rotor center from the elliptic center is approximately 0.4226 of the semi-minor elliptic diameter.

3. The device as defined in claim 1, further characterized by the elliptic cylinder surface and the rotor being configured and located as follows; the rotor center is located on the prolonged minor diagonal, of a rhombus whose minor diagonal is equal to each of its four sides, by a distance from one end of the minor diagonal equal to half the rhombus major diagonal, the rotor radius is equal to the distance between its center and the opposite end of the rhombus minor diagonal, and the elliptic cylinder curvature is made up of two opposite circular arcs each of 120° extent having their centers respectively on the opposite ends of the rhombus minor diagonal and their radii equal to the diameter of the rotor, and two circular arcs each of 60° extent having their centers respectively on the opposite ends of the rhombus major diagonal.

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