United States Patent

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[54] VANE TRACKING IN ROTARY DEVICES

7 Claims, 3 Drawing Figs.

[52] U.S. Cl. 418/26, 418/150

[51] Int. Cl. F01c 21/16

[50] Field of Search 418/24, 25, 26, 27, 31, 150

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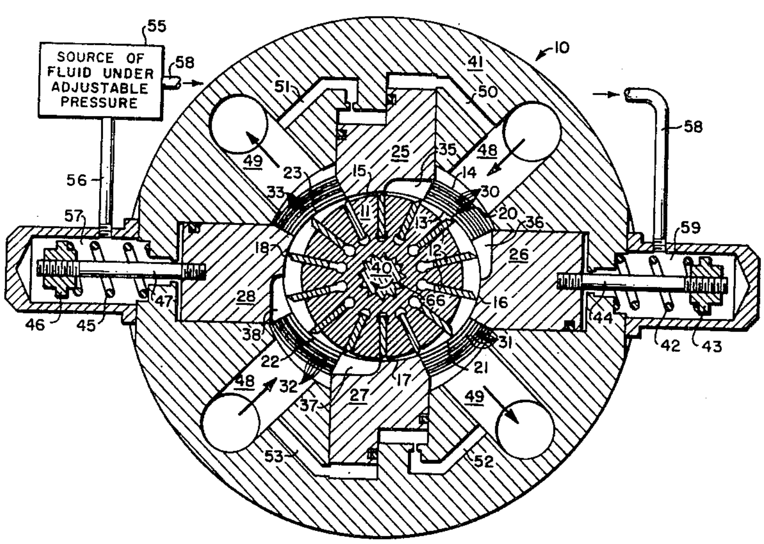
ABSTRACT: A two-lobe sliding-vane rotary moving-fluid device (FIG. 1) comprises a cylindrical rotor **11** having vanes **12** slidable in substantially radial directions therein, the tip of each vane maintaining substantial contact with the inner cylindrical surface **13** of a cam **14** surrounding the rotor as it traverses sealing spaces **15, 16, 17, 18,** and port spaces **20, 21, 22, 23** in the cam alternately during rotation.

The port spaces are formed largely of flexible laminations **30, 31, 32, 33;** so the cam is deformable by adjusting forces against its rigid portions **25, 26, 27, 28** to change its shape and thus to vary the fluid displacement by adjusting the relative positions of the rotor and the sealing spaces.

Throughout the range of displacement positions, any appreciable radial sliding of a vane is only inward as it traverses and maintains substantial contact with the inner surface of each sealing space. Such surface is substantially circular in cross section (FIG. 2), and relative movement of the center of rotation **60** of the rotor is substantially along a portion of the radius **73** from the center of curvature **62** of the inner surface to the trailing edge **68** of the sealing space **15,** where the center of rotation can be closer to the sealing space than the center of curvature. The relative movement is substantially along an extension of the radius **74** to the leading edge **71** of the sealing space **16,** where the center of rotation **60** can be farther than the center of curvature **63** of the inner surface of the sealing space.

A fixed-displacement device is similar, except that the cam is not deformable.



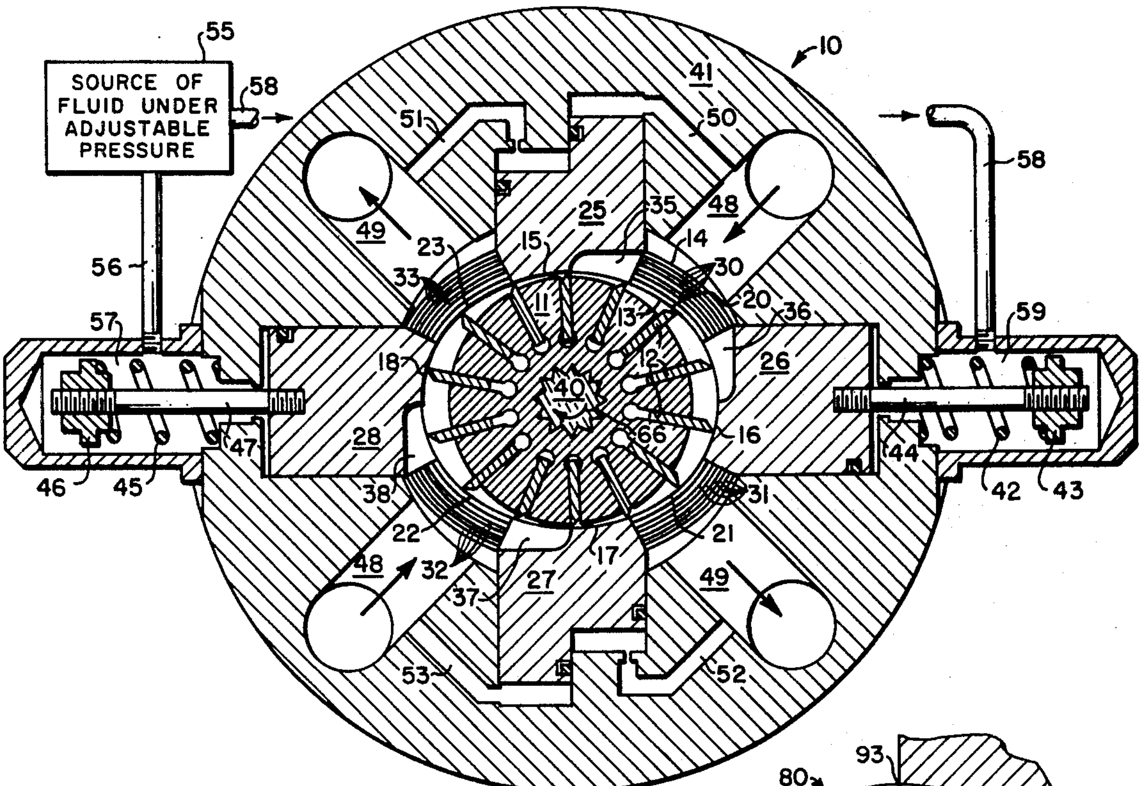


Fig. 1

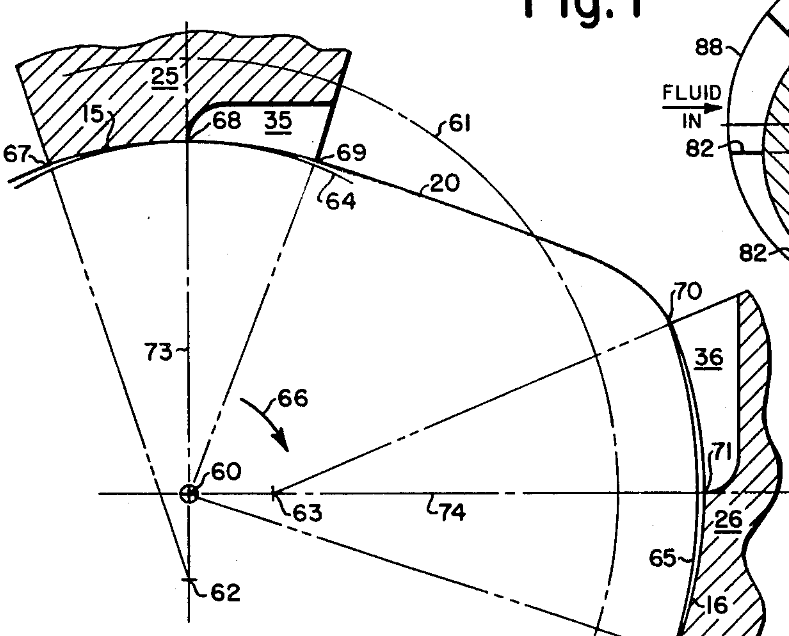


Fig. 2

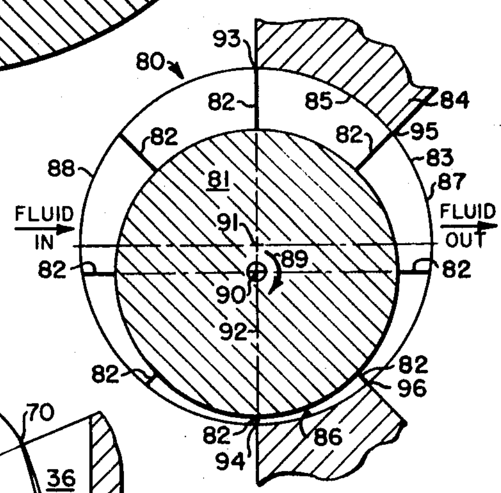


Fig. 3

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VANE TRACKING IN ROTARY DEVICES

BACKGROUND OF THE INVENTION

This invention relates to sliding-vane rotary moving-fluid devices. It has to do particularly with improvements in vane tracking in such devices to avoid any appreciable outward stroking of a vane during any portion of its rotation where it is traversing a sealing space.

The present invention is useful in such devices as the variable-displacement turbine-speed hydrostatic pumps of U.S. Pat. No. 3,407,742 and U.S. Pat. application Ser. No. 771,239, filed Oct. 28, 1968, now U.S. Pat. Nos. 3,514,232, of Robert K. Mitchell, James C. Swain, David L. Thomas, and John P. Wilcox. These patents relate to two-lobe pumps wherein the lobes are enlargeable and reducible to vary the rate of displacement. Both patents disclose such a pump wherein movable sealing spaces are connected by a plurality of bridges across the port spaces to nonmovable sealing spaces, tangency being maintained over the cam surface along which the vane tips track very closely. The latter patent discloses also a pump wherein a deformable cylinder surrounds the rotor and is controllably deformed to provide an inner cylindrical cam surface that is adjustable from circular to substantially elliptical shapes to vary the rate of displacement. In each pump, as in such rotary devices generally, the rate of fluid displacement is varied by adjusting the relative positions of the rotor and at least one sealing space in the cam. Where the sealing space is substantially circular in cross section, the vanes slide radially while traversing the sealing space for all displacements except the one where the center of rotation of the rotor coincides with the center of curvature of the sealing space. In variable displacement devices known before the present invention, the radial sliding is inward during approximately half the travel over the sealing space and outward during the other half.

Appreciable outward sliding of the vanes while sealing causes increased leakage across the tip of the vane and sudden impact of the vane on the cam surface. If the vane has a pivotable tip, the tip can rotate uncontrollably, causing it and the cam ring both to wear out rapidly. Special shapes can be provided in the sealing spaces to reduce or avoid outward radial sliding of the vanes, but such surfaces are difficult and expensive to provide accurately. The present invention avoids appreciable outward radial sliding of vanes traversing a sealing space throughout the range of displacements, even where the inner surface of the sealing space is substantially circular in cross section. Thus manufacturing costs are reduced.

Fixed-displacement devices can also be made more economically with this invention. The cross section of the inner surface of the cam in a single-lobe device can be simply a circle, while in a two-lobe device it can be an approximate ellipse comprising four circle arcs joined at tangent points,

SUMMARY OF THE INVENTION

A typical sliding-vane rotary moving-fluid device according to the present invention comprises a cylindrical rotor having vanes slidable in substantially radial directions therein, the tip of each vane maintaining substantial contact with the inner cylindrical surface of a cam surrounding the rotor as it traverses sealing spaces and port spaces in the cam alternately during rotation. The inner surface of each sealing space is substantially circular in cross section and the center of rotation of the rotor is located substantially on a diameter through the center of curvature of the sealing space to one end of the sealing space, such that any appreciable radial sliding of a vane is inward as it traverses and maintains substantial contact with the inner surface of the sealing space. Where the center of rotation is closer than the center of curvature of the inner surface of a sealing space, it is located substantially on the radius to the trailing edge of the sealing space; and where the center of rotation is farther than the center of curvature of the inner surface of a sealing space, it is located substantially on an extension of the radius to the leading edge of the sealing space.

The device may include means for varying the fluid displacement by adjusting the relative positions of the rotor and a sealing space in the cam in such manner that throughout the range of positions any appreciable radial sliding of a vane is inward as it traverses and maintains substantial contact with the inner surface of the sealing space. The adjusting means typically provides relative movement between the center of rotation of the rotor and a sealing space substantially along a portion of the diameter through the center of curvature of the inner surface to one end of the sealing space. Where the center of rotation can be closer than the center of curvature of the inner surface of the sealing space, the relative movement should be substantially along the radius to the trailing edge of the sealing space. Where the center of rotation can be farther than the center of curvature of the inner surface of the sealing space, the relative movement should be substantially along an extension of the radius to the leading edge of the sealing space.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a transverse cross-sectional view of a typical two-lobe sliding-vane rotary moving-fluid device according to the present invention.

FIG. 2 is a similar view of a portion of the same device, enlarged and mainly schematic to show typical details of the invention.

FIG. 3 is a similar view, simplified and largely schematic, of a typical one-lobe device according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to FIG. 1, a variable-displacement sliding-vane rotary moving-fluid device **10** is shown comprising a pump similar to the pump in FIG. 13 of U.S. Pat. No. 3,514,232 (Ser. No. 771,239), modified to incorporate the present invention. From the disclosure of this embodiment it will be apparent how similar modifications can be made in a routine way to incorporate the invention in other rotary moving-fluid devices such as fluid motors and other pumps such as single-lobe variable-displacement pumps and double-lobe pumps wherein only two of the sealing spaces are movable, as in FIGS. 1-9 of U.S. Pat. Nos. 3,407,742 and 3,514,232 (Ser. No. 771,239).

A cylindrical rotor **11** has vanes **12** slidable in substantially radial directions therein, the tip of each vane **12** maintaining substantial contact with the inner cylindrical surface **13** of a cam **14** surrounding the rotor **11** as it traverses sealing spaces **15, 16, 17, 18** and port spaces **20, 21, 22, 23** in the cam **14** alternately during rotation.

The sealing space **15** extends over the left-half portion of a radially movable block **25**; the sealing space **16** extends over the lower half portion of a radially movable block **26**; the sealing space **17** extends over the right-half portion of a radially movable block **27**; and the sealing space **18** extends over the upper half portion of a radially movable block **28**. Flexible laminations **30**, connected at one end to the block **25** and at the other end to the block **26**, are provided with ports (not shown) extending over the entire sector between the blocks **25** and **26**. Flexible laminations **31**, connected at one end to the block **26** and at the other end to the block **27**, are provided with ports (not shown) extending over the entire sector between the blocks **26** and **27**. Flexible laminations **32**, connected at one end to the block **27** and at the other end to the block **28**, are provided with ports (not shown) extending over the entire sector between the blocks **27** and **28**. Flexible laminations **33**, connected at one end to the block **28** and at the other end to the block **25**, are provided with ports (not shown) extending over the entire sector between the blocks **28** and **25**.

The ports in the laminations **30** communicate with a port **35** in the right-half portion of the block **25** and with a port **36** in the upper half portion of the block **26**. Thus, the port space **20** extends from the middle of the block **25** to the middle of the block **26**. The port space **21** extends from the lower end of the block 26 to the right end of the block 27. The ports in the laminations 32 communicate with a port 37 in the left-half portion of block 27 and with a port 38 in the lower half portion of block 28. Thus, the port space 22 extends from the middle of the block 27 to the middle of the block 28. The port space 23 extends from the upper end of the block 28 to the left end of the block 25. The blocks 25–28 and the laminations 30–33 are shaped and fixedly joined at their adjacent ends in such manner that when the blocks 25–28 are positioned at equal distances from the axis of the shaft 40, about which the rotor 11 rotates, the inner surface of the cam ring 13 is at right circular cylinder coaxial with the shaft 40 and the rotor 11. Thus, the inner surfaces of the blocks 25–28 forming the sealing spaces 15–18 and their respective adjacent ports 35–38 are sectors of the same circle in cross section.

The blocks 25–28 are radially movable from the positions just described where the inner surface 13 of the cam 14 is circular in cross section, through a continuous range of positions to the position shown in FIG. 1 where the upper and lower blocks 25, 27 are substantially closer to the center of the shaft 40 than are the left and right blocks 28, 26, and where the inner surface 13 of the cam 14 is approximately elliptical in cross section. The positions between the two extremes are also approximately elliptical in cross section but of less eccentricity.

The radial positions of the blocks 25–28 can be controlled in any suitable manner. In the device 10 as shown in FIG. 1, the right-hand block 26 is forced outwardly by a compression spring 42 pressing resiliently between the housing 41 and a nut 43 on a rod 44 connected to the block 26. Similarly, the left-hand block 28 is forced outwardly by a compression spring 45 pressing resiliently between the housing 41 and a nut 46 on a rod 47 connected to the block 28. Fluid pressures are applied to the outer ends of the upper and lower blocks 25, 27 from the inlet ports 48 and the outlet ports 49 in the housing 41 through the passages 50, 51, 52, 53, to maintain the blocks 25, 27 firmly in the proper positions and to minimize vibration while the rotor 11 is rotating.

A source 55 provides fluid under adjustable pressure through a conduit 56 to a fluidtight chamber 57 adjacent the housing 41, surrounding the spring 45, the nut 46, and the rod 47, and communicating with the outer end of the left block 28. The source 55 also supplies fluid under adjustable pressure through a conduit 58 to a fluidtight chamber 59 adjacent the housing 41, surrounding the spring 42, the nut 43, and the rod 44, and communicating with the outer end of the right block 26. When the forces against the blocks 28, 26 from the fluid pressure from the source 55 in the chambers 57, 59 is lower than the opposing forces of the springs 45, 42 and the fluid pressures at 48, 49, the cam 14 is maintained at its position of maximum eccentricity and maximum displacement as shown in FIG. 1. The fluid pressure from the source 55 can be adjusted upward to increase the forces against the outer ends of the blocks 28, 26 sufficiently to exceed the opposing forces, and thus to force the blocks 28, 26 inwardly to reduce the eccentricity of the cam 14 and thus to reduce the rate of fluid displacement in the device 10. When the desired displacement is reached, the pressure from the source 55 is automatically reduced to establish equilibrium.

FIG. 2 shows how the present invention avoids appreciable outward radial sliding of a vane as it traverses and maintains substantial contact with the inner surface of a sealing space. When the pressure from the source 55 is adjusted to a value such as to provide zero displacement in the device 10, the inner surface 13 of the cam 14 is substantially circular in cross section and concentric with the center or rotation 60, as is indicated by the interrupted circular arc 61. When the pressure is adjusted to provide a substantial rate of displacement, the upper block 25 is moved downward as shown in FIG. 2 with its center of curvature at a point 62, and the center of rotation 60 is thus closer than the center of curvature 62 to the inner surface of the block 25. At the same time the block 26 moves to the right, away from the center of rotation 60, and its center of curvature 63 is closer to its inner surface than is the center of rotation 60.

To help explain the invention, FIG. 2 includes an auxiliary line 64 which is an arc of a circle drawn about the center of rotation 60 and tangent to the inner surface of the block 25 at its midpoint 68, which is on the trailing edge of the sealing space 15 at its junction with the port 35. Another auxiliary line 65 comprises an arc of a circle whose center is at the center of rotation 60 and which coincides at each end 70, 72 with the inner surface of the right-hand block 26. Considering the rotor as rotating clockwise, as indicated at 66, the arc 64 can represent the locus of the tip of a vane 12 if it were tightly held in a fixed position in the rotor 11 during rotation. Since each vane 12 is slidable in substantially radial directions, and is forced outward by fluid pressure and centrifugal force, its tip actually follows the inner surface of the upper block 25 while traversing it. Thus, the tip of the vane 12 as it traverses the sealing space 15 moves inwardly from the left end point 67 on the leading edge of the sealing space 15, which is farther than the arc 64 from the center of rotation 60, to the midpoint 68 on the trailing edge of sealing space 15, which is at the same distance as the arc 64 from the center of rotation 60. As the vane tip continues to the right end point 69, it moves outwardly from the arc 64. Thus, the radial sliding of the vane is inward as it traverses and maintains substantial contact with the inner surface of the sealing space 15. If the sealing space 15 extended over the right half of the block 25, the vane 12 would have to slide outward appreciably while traversing that part of the sealing space, which could lead to unstable operation and damage to the vane 12 and the cam 14.

As the vane 12 continues to traverse the port space 20 it continues to move outward along the inner surface of the flexible portion of the cam 14. It also moves outward as it traverses the upper half of the inner surface of the block 26, from the upper end point 70 to the midpoint 71 on the leading edge of the sealing space 16. If the port 36 were not provided in this region, the vane would be moving appreciably radially outward in a sealing space. Thus, the port 36 avoids such an undesirable situation. As the vane continues to rotate from the midpoint 71 of the block 26 across the sealing space 16 to the lower end point 72 on the trailing edge of the sealing space 16, it moves radially inward as is apparent by considering the arc 65 which has its center at the center of rotation 60.

From the above explanation, it is seen that the rate of fluid displacement is varied by adjusting the relative positions of the rotor and the sealing spaces in the cam along a portion of the radius from the center of curvature of the inner surface to one end of the sealing space, where the sealing space has an inner surface that is substantially circular in cross section. Where the center of rotation 60 can be closer than the center of curvature 62 of the inner surface of the sealing space 15, the relative movement is substantially along the radius 73 to the trailing edge at 68 of the sealing space 15. Where the center of rotation 60 can be farther than the center of curvature 63 of the inner surface of the sealing space 16, the relative movement is substantially along an extension of the radius 74 to the leading edge at 71 of the sealing space 16. The sealing spaces 17 and 18 are identical in shape and position to the sealing spaces 15 and 16, respectively, but 180° away; so FIG. 2 and the explanation above apply similarly to them.

FIG. 1 can also be considered to illustrate a fixed-displacement device wherein the cam 14 is maintained in the shape and position shown. Of course the construction can be greatly simplified in obvious ways where it is not intended to vary the displacement.

In FIG. 3, a single-lobe rotary moving-fluid device 80 comprises a cylindrical rotor 81 having vanes 82 (only the protruding portions of which are shown schematically in FIG. 3) that are slidable in substantially radial directions therein, the tip of each vane 82 maintaining substantial contact with the inner cylindrical surface 83 of a cam 84 surrounding the rotor 81 as it traverses sealing spaces 85, 86 and port spaces 87, 88 in the cam 84 alternately during rotation clockwise, as indicated at 89, about the center of rotation 90.

The inner surface **83** of the cam **84** is substantially circular in cross section, the center of curvature being at **91**. The center of rotation **90** of the rotor is located on the diameter **92** through the center of curvature **91** to one end **93** (on the leading edge) of the sealing space **85**, and to one end **94** (on the trailing edge) of the sealing space **86**. The device **80** can be either a fixed-displacement device with the center or rotation **90** located as shown in FIG. **3**, or a variable displacement device wherein, to reduce the rate of displacement, the center of rotation **90** can be moved to other positions along the diameter **92** toward the center of curvature **91**.

From FIG. **3** it is apparent that, after it traverses the fluid-input port space **88**, the tip of a vane **82** as it traverses the sealing space **85** moves inwardly from the left end point **93**, on the leading edge, which is farther from the rotor **81**, to the right end point **95**, on the trailing edge, which is closer to the rotor **81**. It is apparent also that, after it traverses the fluid-output port space **87**, the tip of a vane **82** as it traverses the other sealing space **86** moves inwardly from the right end point **96**, on the leading edge, to the left end point **94**, on the trailing edge. Thus any appreciable radial sliding of a vane **82** is inward as it traverses and maintains substantial contact with the inner surface of each sealing space **85, 86**.

The sealing space **85** could be located clockwise from the position shown and the sealing space **86** could be located counterclockwise from the position shown, thus providing a margin for inaccuracy. The principle limitation on their positions is that they may not extend appreciably to the left of the diameter **92**, where the vanes **82** move radially outward. In some devices a small amount of outward movement can take place without damaging the vanes or the cam.

Similarly, in the two-lobe device of FIG. **1** the ports **35–38** in the blocks **25–28** may extend beyond the respective vertical and horizontal axes **73, 74** (FIG. **2**) where a margin for inaccuracy is desired. Conversely, the sealing spaces **15–18** may extend slightly beyond the respective axes **73, 74** in devices wherein a small amount of outward movement of the vanes **12** will not damage the vanes **12** or the cam **14**.

The invention of course includes such deviations from the relative locations in the drawings, and the claims are thus to be construed broadly to permit them.

The drawings are not to scale. Spacings, eccentricities, etc. are exaggerated to facilitate the understanding of the invention.

It will be understood of course that while the forms of the invention herein shown and described constitute preferred embodiments, it is not intended to illustrate all of the possible and equivalent forms or ramifications of the invention. It will also be understood that the words used are words of description rather than of limitation and that various changes such as changes in shape, relative size, and arrangement of parts may be substituted without departing from the spirit or scope of the invention herein disclosed.

I claim:

1. A sliding-vane rotary moving-fluid device, comprising:

a cylindrical rotor having vanes slidable in substantially radial directions therein, the tip of each vane maintaining substantial contact with the inner cylindrical surface of a cam surrounding the rotor as it traverses sealing spaces and port spaces in the cam alternately during rotation;

wherein the inner surface of each sealing space is substantially circular in cross section and the center of rotation of the rotor is located substantially on a diameter through the center of curvature of the sealing space to one end of the sealing space, such that any appreciable radial sliding of a vane is inward as it traverses and maintains substantial contact with the inner surface of the sealing space.

2. A device as in claim **1**, wherein the center of rotation is closer than the center of curvature of the inner surface of a sealing space and substantially on the radius to the trailing edge of the sealing space.

3. A device as in claim **1**, wherein the center of rotation is farther than the center of curvature of the inner surface of a sealing space and substantially on an extension of the radius to the leading edge of the sealing space.

4. A device as in claim **1**, including means for varying the fluid displacement by adjusting the relative positions of the rotor and a sealing space in the cam in such manner that throughout the range of positions any appreciable radial sliding of a vane is inward as it traverses and maintains substantial contact with the inner surface of the sealing space.

5. A device as in claim **4**, wherein the adjusting means provides relative movement between the center of rotation of the rotor and a sealing space substantially along a portion of the diameter through the center of curvature of the inner surface to one end of the sealing space.

6. A device as in claim **5**, wherein the center of rotation can be closer than the center of curvature of the inner surface of the sealing space, and the relative movement is substantially along the radius to the trailing edge of the sealing space.

7. A device as in claim **5**, wherein the center of rotation can be farther than the center of curvature of the inner surface of the sealing space, and the relative movement is substantially along an extension of the radius to the leading edge of the sealing space.