United States Patent [19]

Foster

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[45] **July 24, 1973**

[54] **ROTARY VANE DEVICE FOR COMPRESSOR, MOTOR OR ENGINE**

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[21] Appl. No.: **248,866**

Related U.S. Application Data

[63] Continuation of Ser. No. 41,008, May 27, 1970, abandoned.

[52] **U.S. Cl.** **123/8.05,** 123/8.09, 418/137, 418/262

[51] **Int. Cl.** **F02b 53/00**

[58] **Field of Search** 123/8.05, 8.09; 418/260, 262, 136, 137, 234

[56] **References Cited**

UNITED STATES PATENTS

2,037,450	4/1936	Bancroft	123/8.09
1,427,692	8/1922	Mahon	123/8.05
2,920,610	1/1960	Breelle	418/196
1,848,754	3/1932	Lanzerotti-Spina	418/136
3,356,292	12/1967	Brewer	418/137
3,457,872	7/1969	Potts	418/137 X

FOREIGN PATENTS OR APPLICATIONS

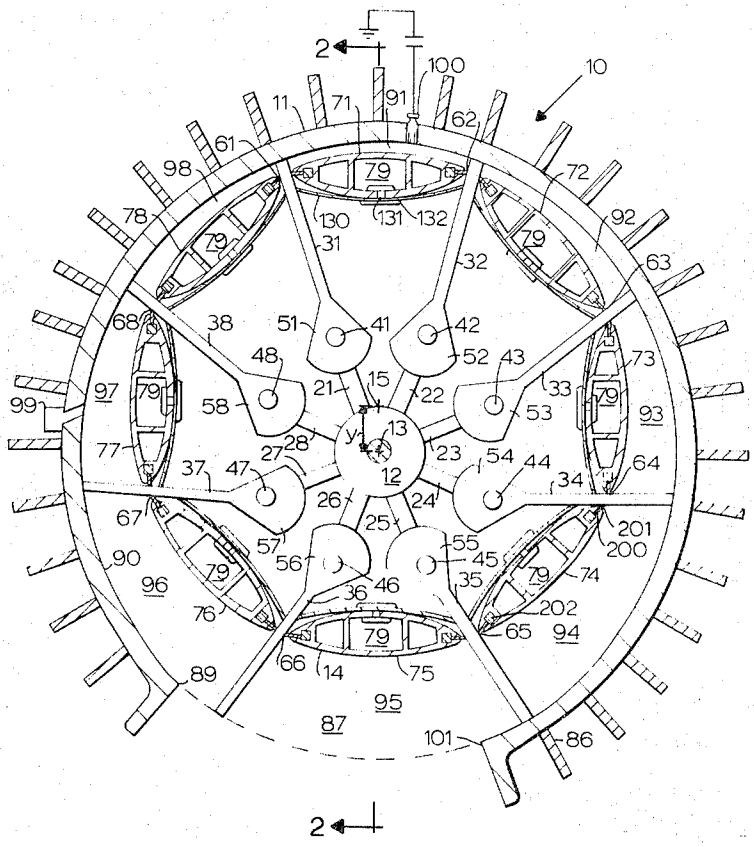
19,896	5/1915	Great Britain	418/234

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[57] **ABSTRACT**

A vane device for use as an engine, a compressor, or a motor. At least three vanes are pinned to a central hub and extend through respective slots in a generally cylindrical drum with its axis parallel to and displaced radially from that of said hub, the slots guiding the radial position of the vanes. Synchronizing means, such as a gear train, cause the hub and drum to rotate in the same direction and at the same speed, with the vanes reciprocating and oscillating in the guide slots. A housing encloses the vanes and cooperates with them and the drum to provide a series of working spaces, one for each vane to compress or expand a fluid. Intake and exhaust ports lead fluid into and from the working spaces.

12 Claims, 8 Drawing Figures



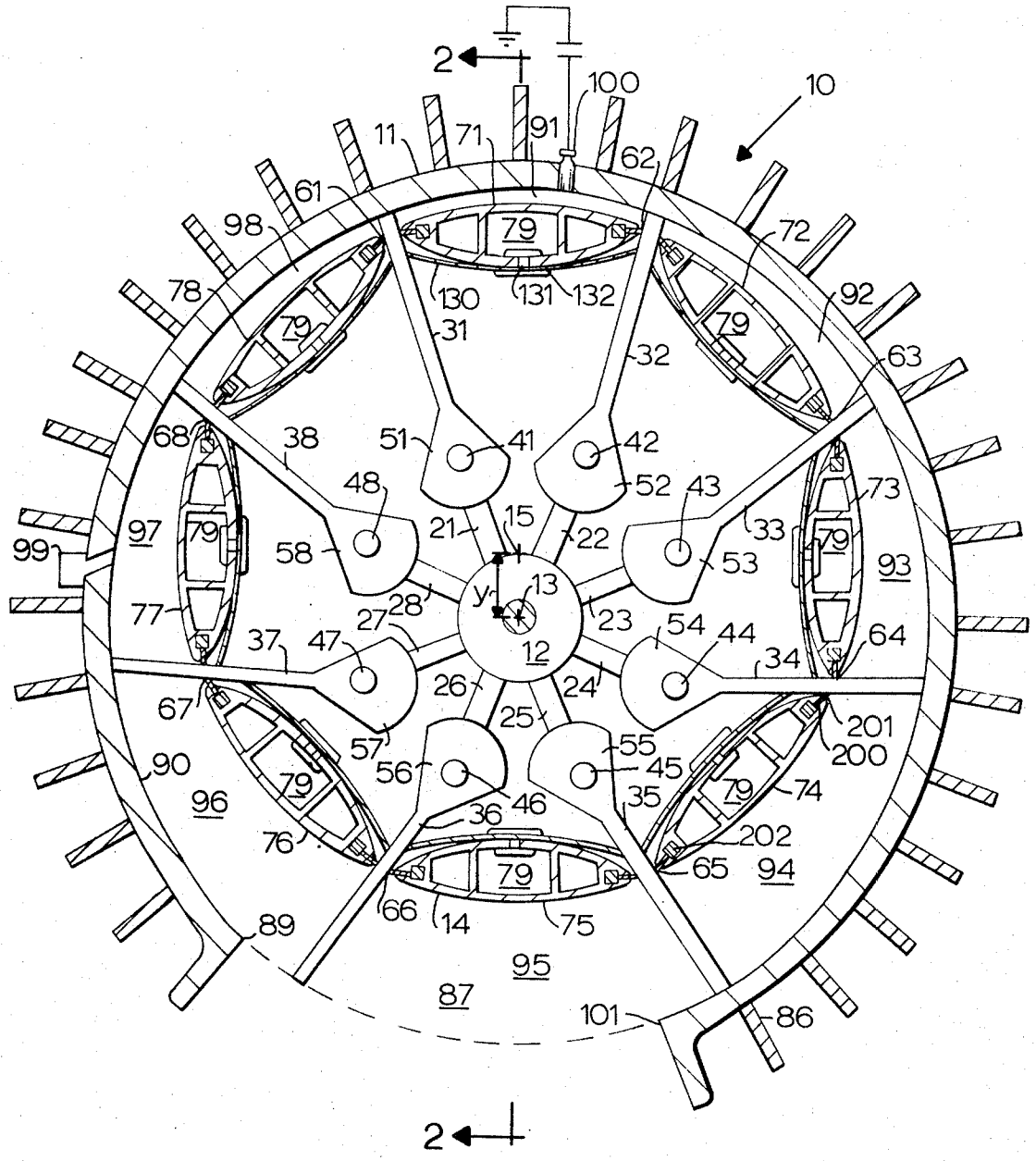


FIG. 1

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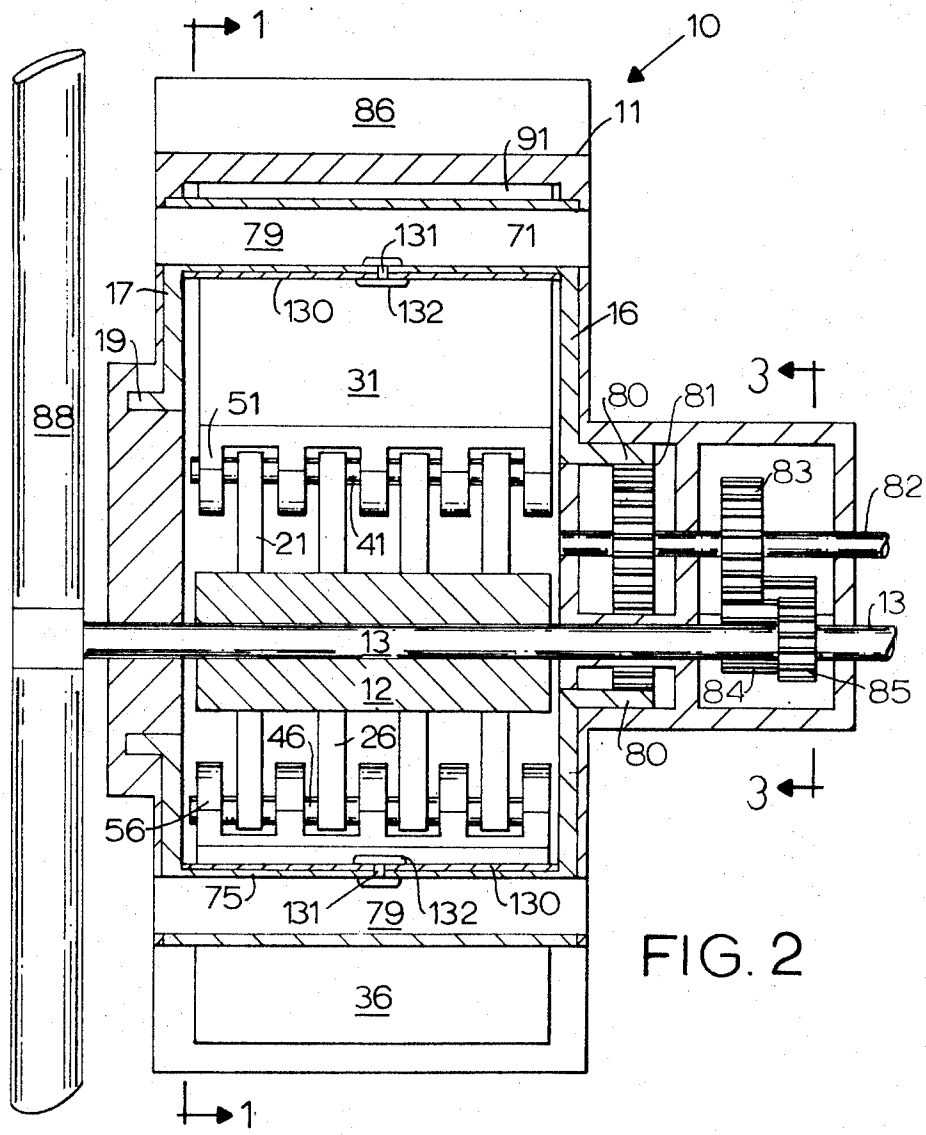

1
10
86
11
91
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132
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19
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3
88
51
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81
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131
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132
130
36
1

FIG. 2

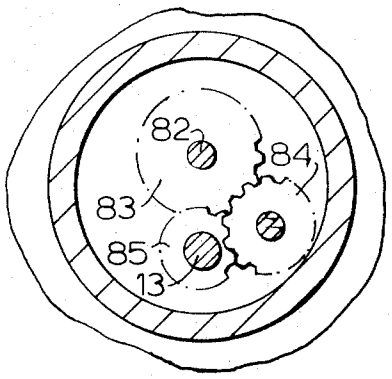

82
84
83
85
13

FIG. 3

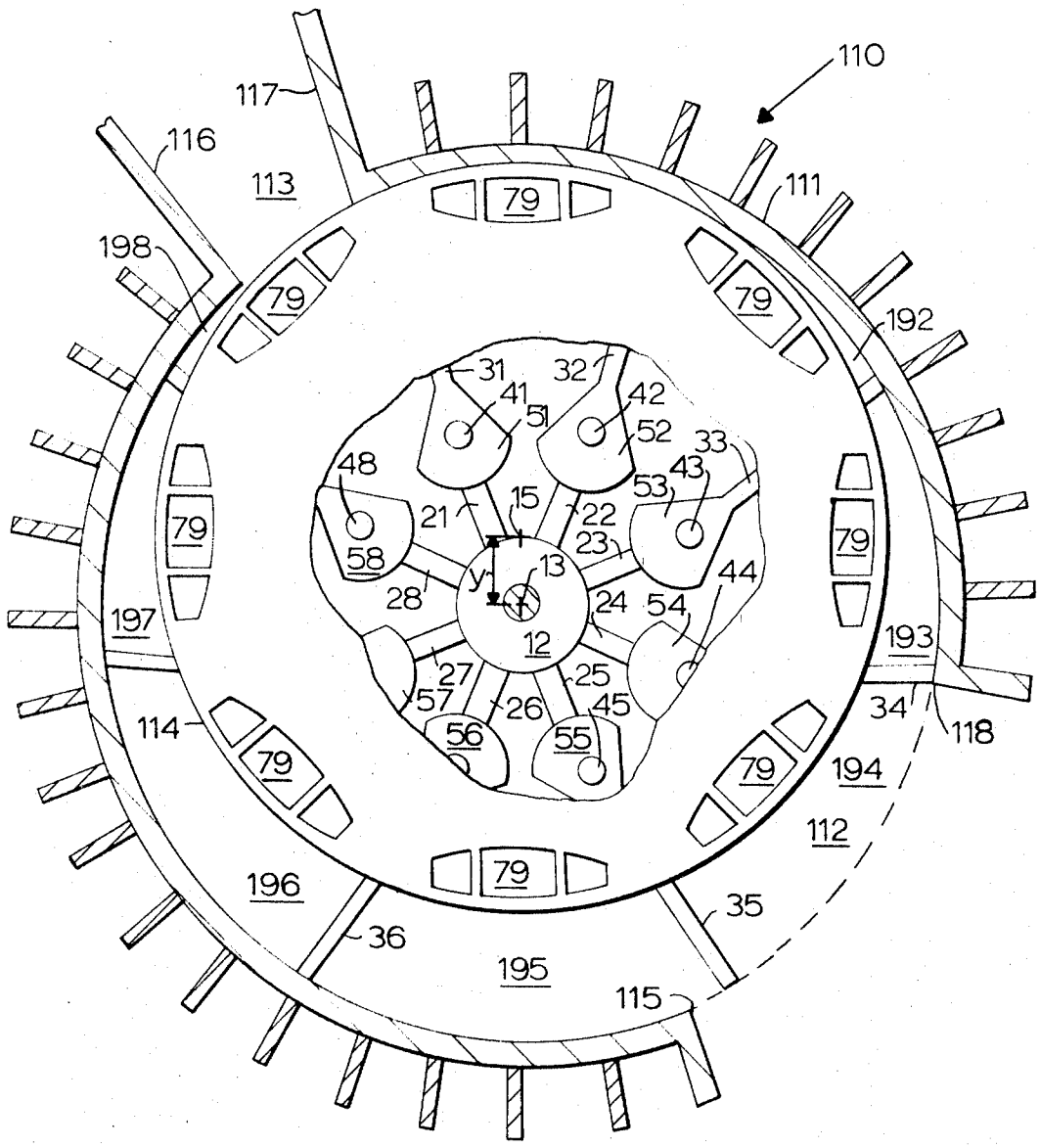


FIG. 4

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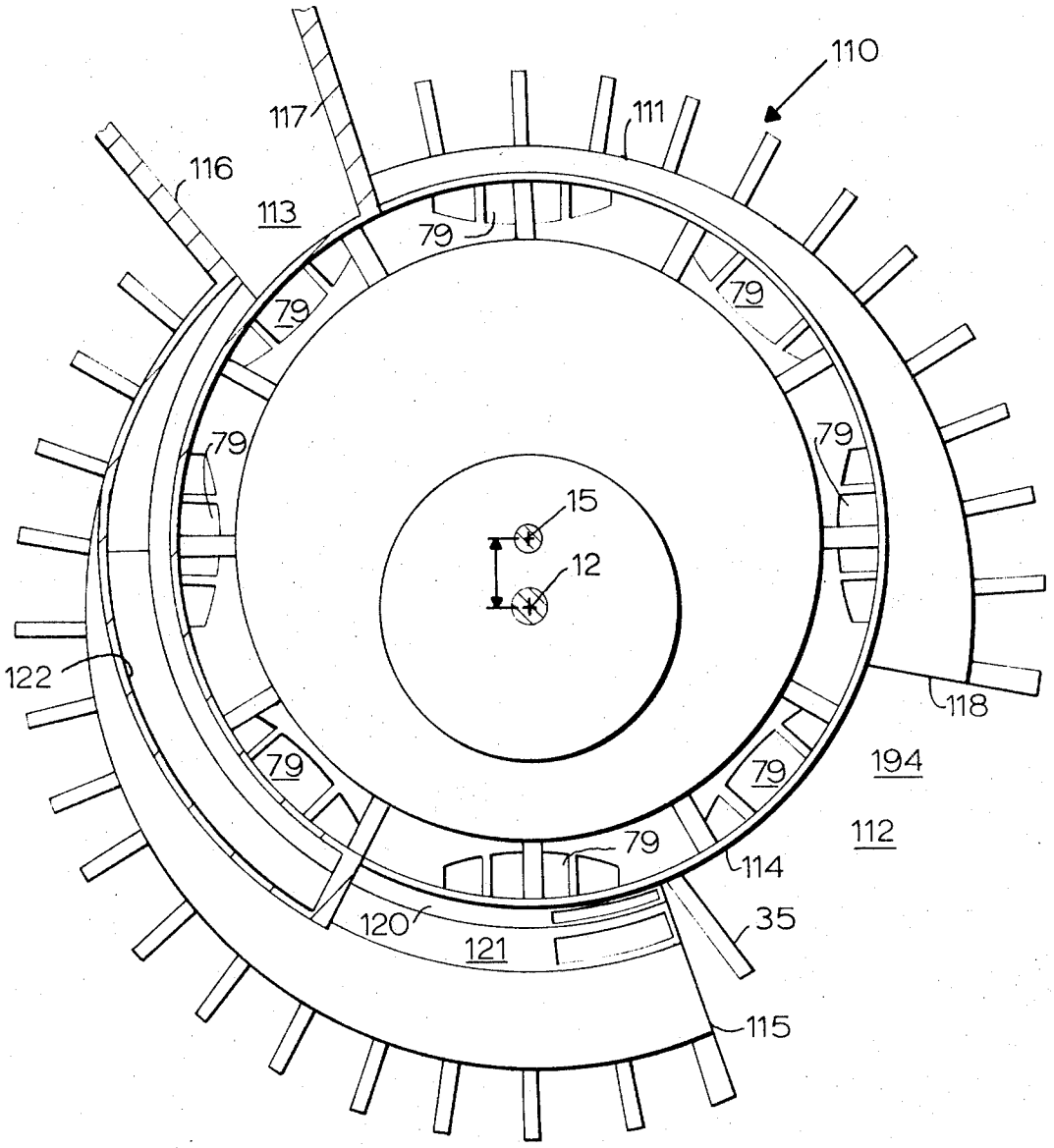


FIG. 5

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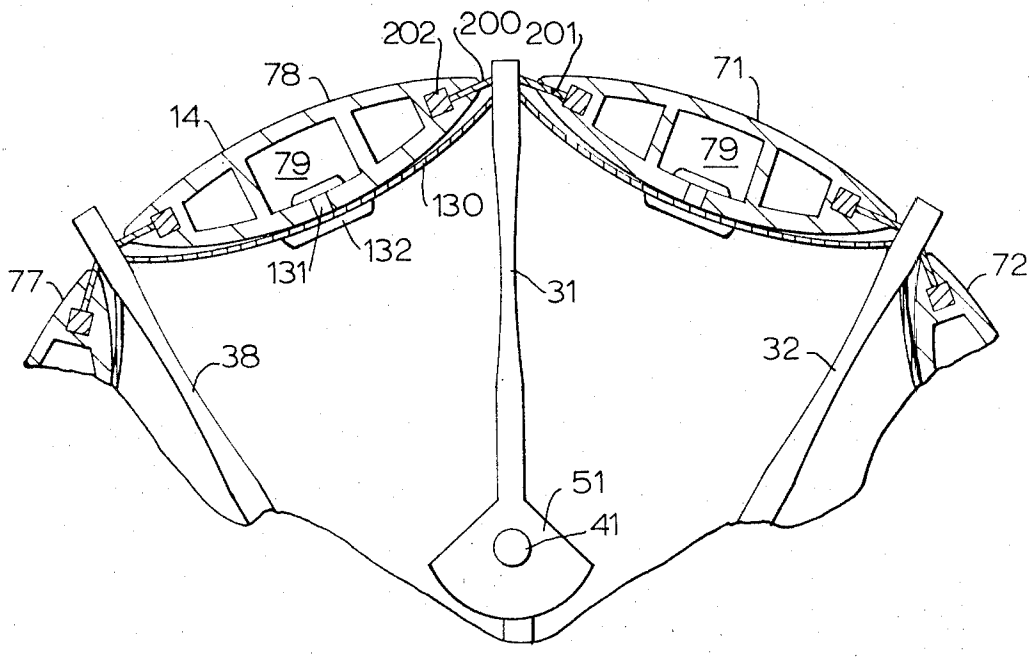
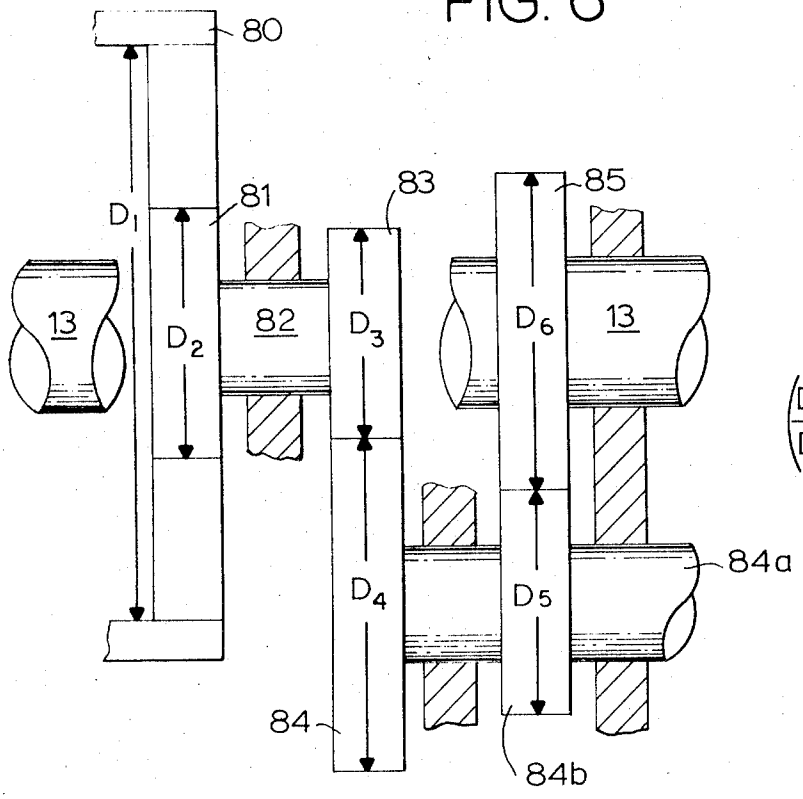


FIG. 6



$$\left(\frac{D_1}{D_2}\right)\left(\frac{D_3}{D_4}\right)\left(\frac{D_5}{D_6}\right)=1$$

FIG. 7

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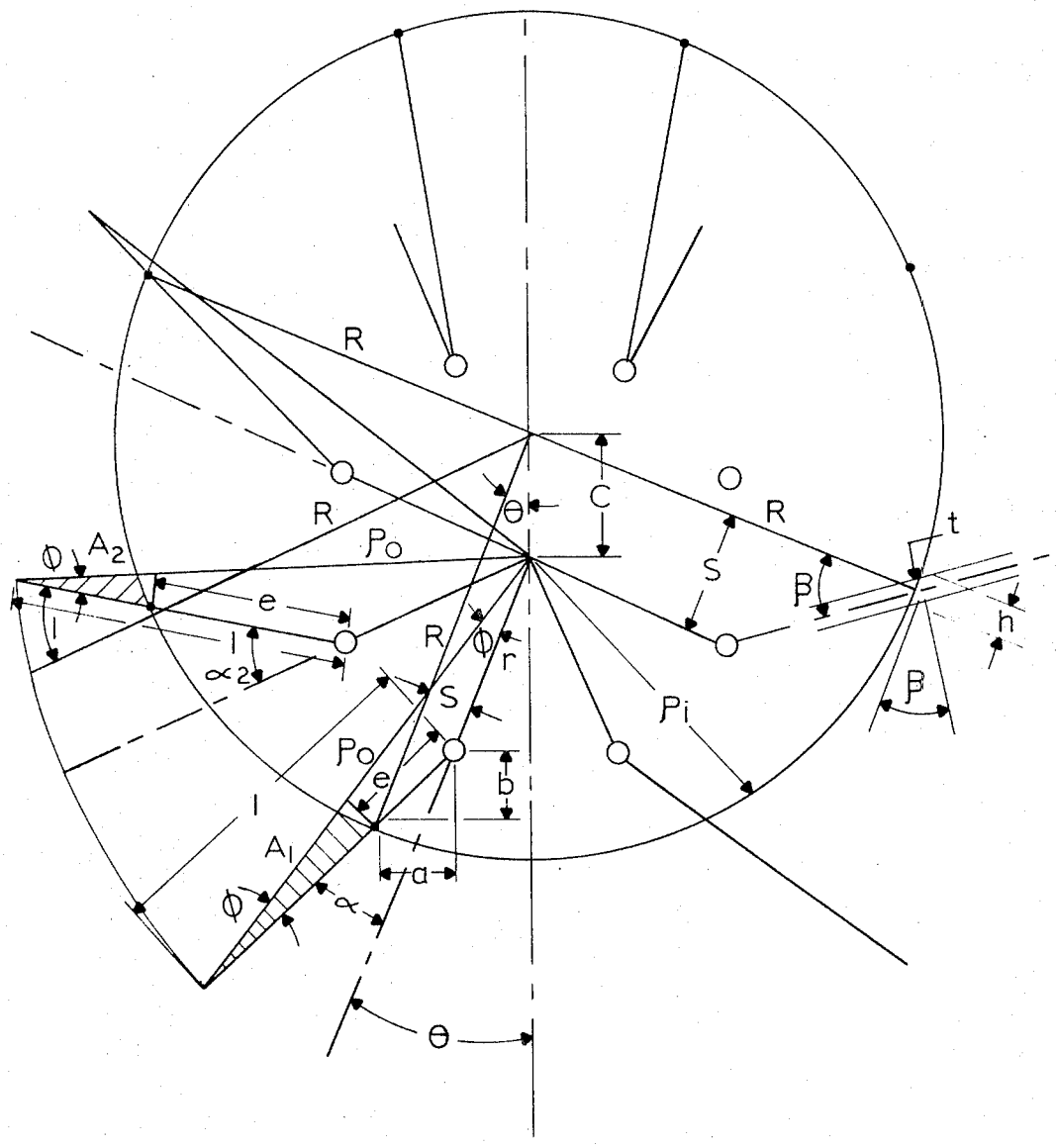


FIG. 8

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ROTARY VANE DEVICE FOR COMPRESSOR, MOTOR OR ENGINE

This is a continuation of application Ser. No. 41,008, filed May 27, 1970 and now abandoned.

Reference is made to Disclosure Document No. 001767 of Apr. 3, 1970.

This invention relates to a rotary mechanism for vane compressors, vane hot gas or steam motors or steam engines, and vane internal combustion engines.

A feature of the rotary vane device of this invention is that the vanes are pinned to a central hub-shaft, and it has a separate circular drum to help transmit torque through the vanes and to guide the radial direction of the vanes. The vanes are pinned at their centers of gravity to the central hub-shaft, so that they can oscillate back and forth as the central hub-shaft rotates; as a result, the mechanism is kept in dynamic balance. The central hub shaft supports the full centrifugal pull of the vanes; consequently, they have no friction drag at their tips where they nearly (but not quite) touch the housing.

The central hub-shaft and the circular drum both rotate at the same speed and in the same direction, but the center of rotation of the circular drum is offset from the center of rotation of the central hub-shaft. The radius of the circular drum is smaller than the radial distance from the hub center to the tips of the extended vanes in every position of their rotation. The circular drum preferably has equally spaced axial slots at its outer periphery, one for each vane; these axial slots are preferably just big enough so that the vanes are forced to oscillate and reciprocate in them as the drum and shaft rotate. As the shaft and drum rotate and the vanes are forced to rotate and oscillate, their tips form a circumscribed surface.

The housing of my new rotary vane device is slightly larger than the circumscribed surface of the vanes; thus there is no friction between the vanes and the housing. The housing may be provided with an intake port and an exhaust port. The space bounded between two adjacent vanes, the cylindrical surface of the drum between these vanes, and the cylindrical and disc surfaces of the housing constitutes the working space. There may be three or more working spaces in each device, and the volume of each working space varies as the drum and the hub-shaft rotate in the stationary housing. For example, the maximum volume of this working space is 180° out of phase with its minimum volume.

The rotary vane device of this invention may be used as a compressor, as a motor for expanding compressed gases or steam, or as an internal combustion engine, — depending upon how the intake and exhaust ports are arranged.

For a compressor, the intake port is closed by a rotary vane just after the working space is largest; as the vanes and drum rotate, decreasing the volume of the working space, they give an isentropic compression of the trapped gases. The compressed gases are then forced out of the working space through a discharge port located where the working space is smallest.

For a motor to expand compressed gases for useful work, the intake port is opened where the working space is smallest, and it may have an adjustable device to regulate the shut-off point of the intake port. When the prescribed amount of compressed gas is in the working space, the vanes trap this compressed gas and expand it until the working space is at its largest volume; then the exhaust port opens to exhaust low pressure gases as the working space becomes smaller.

For an internal combustion engine, one port may serve for intake, exhaust, and scavenging, and this port is located where the working space is largest. A fan may blow the exhaust gases out of the port and cool the vane and drum surface. The vanes close the working space, and a fresh charge is compressed isentropically or approximately so until the working space is the smallest; then fuel is exploded in this space, as by means of spark ignition, and the gases are heated by constant volume to increase the pressure. The high pressure gases force the vanes and drum to rotate, so that the working space increases as the gases expand adiabatically or approximately so to do useful work on the engine shaft. The engine maximum expansion space may be larger than the engine intake space; thus the hot gases may expand further than they would in the corresponding piston engine to give more work per pound of air and consequently higher efficiencies.

In the drawings:

FIG. 1 is a view in section (which may be considered as taken along the line 1—1 in FIG. 2) normal to the rotating shaft for the hub and drum, of a rotary vane device embodying the principles of the invention, when employed as an internal combustion engine.

FIG. 2 is a fragmentary view in section taken along the line 2—2 in FIG. 1 and showing a gear box for synchronizing the shaft and the drum of the engine of FIG. 1.

FIG. 3 is a view in section taken along the line 3—3 in FIG. 2, showing the end view of the gears.

FIG. 4 is a fragmentary view in section of a modified form of the device that may be used as a compressor or a motor, depending on whether the hub-shaft and the drum rotate clockwise, when it acts as a compressor, or counterclockwise, when it acts as a motor or steam engine.

FIG. 5 is an end view in section of the engine of FIG. 4 showing the adjustable sliding circular valve for regulating the cutoff point for steam or compressed gas expansion in the vane motor.

FIG. 6 is a fragmentary detail view of a portion of the motor, showing a spring seal ring to contain the lubricating oil inside the drum.

FIG. 7 is a fragmentary enlarged view, partly diagrammatic, of the gear box with part of the hub shaft broken away to show parts otherwise obscured.

FIG. 8 is a diagram relative to the geometry of the vanes, hub, and drum as they rotate.

DESCRIPTION OF THE PARTS AND THEIR OPERATION

The vane engine 10 of FIGS. 1 to 3 comprises a generally cylindrical housing 11. A hub-shaft 12 rotates about a center line 13, having its bearings on or supported by the housing 11 (FIG. 2). In the design shown, the hub-shaft 12 has eight equally spaced piano hinges 21, 22, 23, 24, 25, 26, 27, 28, (which may be pinned at the ends only or as shown) and eight vanes 31, 32, 33, 34, 35, 36, 37, and 38 are pinned at their center of gravity to respective piano hinge points 21, 22, 23, 24, 25, 26, 27, and 28 by means of shafts 41, 42, 43, 44, 45, 46, 47 and 48. Each of the vanes 31, 32, 33, 34, 35, 36, 37, 38 may have a counter mass 51, 52, 53, 54, 55, 56, 57, 58, so that as the vanes oscillate about their respective shafts 41, 42, 43, 44, 45, 46, 47, 48 the hub-

shaft 12 remains in dynamic balance as it rotates. Although eight vanes are shown in FIG. 1, any number of equally spaced vanes greater than three may be used.

A drum 14 rotates about a center line 15 which is displaced from the hub center line 13 by the distance y. The drum 14 has its bearing on the housing 11. The drum 14 and the hub-shaft 12 are synchronized to rotate in the same direction and at the same rotating speed. The drum 14 has slots 61, 62, 63, 64, 65, 66, 67, 68 at its outer diameter and these slots are just large enough for the corresponding vanes 31, 32, 33, 34, 35, 36, 37, 38 to slide and oscillate in as the hub-shaft 12 and the drum 14 rotate. Between adjacent axial slots 61, 62, 63, 64, 65, 66, 67, 68 there may be gusseted arch or beam sections 71, 72, 73, 74, 75, 76, 77, 78 with cooling ports or tubes 79. The drum 14 may have discs 16 and 17 (FIG. 2) at its ends for supporting the gusseted arc sections 71, 72, 73, 74, 75, 76, 77, 78. The discs 16 and 17 also support the bearings 18 and 19 for the drum 14 on the housing 11. The disc 16 may also be provided with an internal gear 80 (FIG. 3).

The mechanism for synchronizing the hub-shaft 12 and the drum 14 may comprise the internal gear 80 and a meshing spur gear 81, which is keyed to a shaft 82 that has its bearings on the housing 11. Also keyed to shaft 82 is a second spur gear 83. The spur gear 83 may be meshed with a pinion gear 84, which is also meshed to a third spur gear 85, or, as shown in FIG. 7, the gear 84 is keyed to a shaft 84*a* that also carries a gear 84*b* meshed to the gear 85. The spur gear 85 is keyed to the hub-shaft 12. The pinion gear 84 has its shaft bearings on the housing 11. The pitch diameter and teeth of the gears 80, 81, 83, 84 and 85 are prescribed so that the hub-shaft 12 and the drum 14 are synchronized to rotate in the same direction and at the same rotating speed.

As shown in FIG. 7, the gears have the following pitch diameters:

gear	diameter
80	D_1
81	D_2
83	D_3
84	D_4
84*b*	D_5
85	D_6,

and the pitch diameters are related so that

$$(D_1/D_2) \times (D_3/D_4) \times (D_5/D_6) = 1.$$

Power may be transmitted through the shaft 12 or the shaft 82 or both of them. The housing 11 may be provided with cooling fins 86.

For the engine device of FIG. 1, the housing 11 may be provided with an intake scavenging and exhaust port 87. A fan 88, which is keyed to the hub-shaft 12 may be used to blow a fresh charge of air through the open port 87 to help scavenge the expanded gases out of the exhaust, to cool the vanes 31, 32, 33, 34, 35, 36, 37 and 38 and to cool the outer surface of each drum beam section 71, 72, 73, 74, 75, 76, 77, 78 when it is at the port 87. Also the fan air flows past the cooling fins 86 to cool the engine housing 11 and blows air through the cooling passages 79 between the gussets and the arcuate segments in the beam elements 71, 72, 73, 74, 75, 76, 77, and 78.

The hub-shaft 11 rotates clockwise, and when, for example, the vane 36 moves past the position 89 of the housing 11 a fresh charge is trapped in a working space 96 bounded by the adjacent vanes 36 and 37, the outer surface of the beam element 76, and the inner surface 90 of the housing 11 between the tips of the vanes 36, 37 and side disc section of the housing 2. Each of the adjacent vanes 31, 32, 33, 34, 35, 36, 37, 38 has a working space 91, 92, 93, 94, 95, 96, 97, 98. (For a three vane engine there would be three working spaces; for every vane, no matter how many, there is a corresponding working space.) A fuel injector 99 may inject fuel into each working space 91, 92, 93, 94, 95, 96, 97, 98, in turn as it moves past it.

As the hub-shaft 11 and the drum 14 move clockwise they force the vanes 31, 32, 33, 34, 35, 36, 37, 38 to follow a prescribed movement and the working space 91, 92, 93, 94, 95, 96, 97, 98 becomes smaller, thus compressing the gases trapped in it in a manner approaching isentropic compression. When each space is in the top position (where the space 91 is in FIG. 1), it has been reduced to its smallest volume, and a spark ignition system 100 is timed to explode the fuel in the space 91 and heat it substantially by a constant volume process to increase its pressure and force the vanes to turn the hub-shaft 12 clockwise, so the hot gases will expand and do work on the engine shaft. When the vanes 31 etc., reach the position 101 of the housing 11, the hot expanded gases in the space 91 etc., are exhausted centrifugally by the centrifugal action of rotation. Also the fan 88 forces the exhaust gases to flow axially out of the port 87.

In FIGS. 4 and 5 the rotary vane compressor or motor 110 has most of the same parts as the engine 10 and are given the same reference numerals. The basic differences are that the fuel injector 99 and the spark ignition system 100 are eliminated, and in place of the common exhaust, scavenging, and intake port 87 shown for the engine 10, the housing 111 of the compressor or motor 110 has an intake port 112 separate from the discharge port 113, and these ports 112 and 113 are located diametrically opposite each other. Also, the vanes 31, 32, 33, 34, 35, 36, and 37 are practically inside the drum 114, when its respective working space 191, 192, 193, 194, 195, 196, 197, 198 is at its minimum volume, which is equal to the working tolerances between the housing 111 and the drum 114 multiplied by the vane width.

When operating a vane compressor 110, the intake port 112 is closed as the vane 31, 32 etc., is forced past the edge 115 of the port 112 by means of clockwise rotation of hub-shaft 12 and the drum 114. The working space 191, 192 etc., may be close to its largest volume just after the vane 31, 32, etc., closes the intake port 112 at the station 115. As the compressore rotates clockwise, the working space 191, 192 etc., is reduced, and the trapped gases are compressed approximately adiabatically until the vanes 31, 32 etc., move past the station 116 in the housing 111 to open the space 191, 192 etc., to the discharge port 113. The compressed gases are preferably forced out of the space 191, 192 etc., through the discharge port 113 into a compressed gas accumulator (not shown). When the vanes 31, 32 etc., rotate past a station 117, a small volume of compressed gas is trapped in the space 191, 192 etc., this trapped compressed gas expands approximately isentropically and does work on the vanes 31, 32, etc., as the space 191, 192 etc., increase. When the vanes 31, 32 etc., pass a station 118, the compressed gas in the space 191, 192 etc., is substantially equal to the pres-

sure of the gas in the intake port **112**. In order to increase the volumetric efficiency of the compressor, the volume of space **191, 192**, etc. as the vane **31, 32** etc. moves past the station **117** should be kept to a minimum.

When the device **110** is operating as a vane motor or steam engine, the motor turns in a counterclockwise direction. compressed gas or steam, etc., flows from the accumulator, not shown, through the port **113**, which is now the intake port, into the working space **191, 192** etc. After the vanes **31, 32**, etc., move past the station **116**, the compressed gases are trapped in the working space **191, 192** etc. As the motor rotates counterclockwise, the working space **191, 192** etc., increases in volume and the compressed gases expand approximately isentropically to do work on the vanes **31, 32** etc., until they move past the station **115** to open port **112**, which is now the exhaust port. When the exhaus port **112** is open, the pressure in the working spaces **191, 192** etc., is substantially the same as the gases in the exhaust port **112**, except when the cutoff point is increased. After the vane **31, 32** etc., moves past the station **118**, gases are trapped in the space **191, 192**, etc.; this trapped gas is isentropically approximately compressed back to the pressure in the accumulator as the working space **191, 192**, etc. is reduced. In order to increase the efficiency of the motor, the mass of gas which is compressed back to the accumulator pressure is designed to be a minimum. When the vane **31, 32**, etc., rotates past the station **117**, the compressed gases are returned back to the intake port **112** to be combined with more compressed gases for another expansion work cycle.

In order to increase the motor torque per revolution an arcuate cutoff valve **120** (FIG. **5**) may be turned counterclockwise to give the desired cutoff volume **191, 192**, etc. For full admission, an arcuate valve **121** may be turned counterclockwise. The compressed gases flow axially from a chamber **122** through the arc ports into the working spaces **191, 192**, etc.

In order to contain lubricating oil inside the drum **14** or **114**, leaf spring scrapers **130** (FIG. **6**) may be used to scrape the oil of the vanes **31, 32** etc., and keep it inside the drum **14** for lubricating the pivot shafts **41, 42, 43, 44, 45, 46, 47, 48**, the bearings for the hub-shaft **12** and the bearings **18** and **19** for the drum **14**. The scrapers **130** may be secured to each bridge section **71, 72, 73, 74, 75, 76, 77, 78** by means of screws **131** and a nut plate **132** or a quick disconnect clamp. The beam section **14** has an arcuate surface for the spring **130** to follow as it flexes; so it will have fatigue stresses which are below the endurance limit of the spring steel **130**. As the vanes **31, 32**, etc., reciprocate and oscillate in the slots **61, 62** etc., the leaf spring **130** scrapes the excess lubricating oil of the vanes **31, 32** etc., so it will be contained inside the drum **14**; just sufficient oil is left on the vane **31, 32** etc., to lubricate the rubbing surface between the vanes **31, 32**, etc., and the slots **61, 62**, etc.

In order to limit the flow of compressed gas into the drum **14** to a minimum, seal bars **200** may be provided in axial slots **201** in the ends of the beam arcs **71** etc. that bear on the vanes **31** to **38**. Metal springs **202** or other fluid pressure means may be used to keep the seal bars **200** tight against the vanes, and the bars **200** fit snugly in the axial slots **201**, thus a minimum flow of compressed gas passes from the working space **91-98** into the drum **14**.

The geometry of the rotary vanes is illustrated in FIG. **8**. When a vane **31** is in its zero θ position, the radial line R from the centerline of the drum **14** passes through the centerline of the hub-shaft **11** and through the pivot point of this vane **31**. This radial line R also passes through the centerline of the vane **31** and is collinear with the radial line r from the centerline of the hub-shaft **11**. Thus, the angle α between the centerline of the vane **31** and the radial line r is also zero when $\theta = 0$. $P_o = r + l = P_o$ maximum.

As the hub-shaft **11** and the drum **14** rotate clockwise, the angle α increases, and the blade tip leads the rotor, and the radial lines r and R remain parallel to each other. The vane **31** (whose length is l) bears on the drum **14** (R) at a distance e from the pivot point. Thus, the tip of the vane l will be at a radial distance P_o from the centerline of the hub. As the vane rotates from its $\theta = 0$ position to its $\theta = 90° = \pi/2$ radians position, the angle α increases and reaches a maximum when $\theta = 90°$; likewise, the radial distance P_o is a minimum when $\theta = 90°$.

As the vane rotates past its $\theta = 90°$ position, the angle α decreases, and the radial distance P_o increases until $\theta = 180° = \pi$ radians, where $P_o = r + l = P_o$ maximum again, and where $\alpha = 0$ again.

As the vane rotates past its $\theta = 180°$ position, the angle α becomes negative, and the vane tip lags behind the rotor. The radial lines r and R remain parallel to each other, and the radial distance P_o from the hub centerline to the tip of the vane l again decreases until the vane reaches its $\theta = 270°$ position, where P_o is at its minimum radial position again and the angle α is at its negative maximum.

As the vane rotates past its $\theta = 270° = 3\pi/2$ position, the angle α decreases and the radial distance P_o increases until $\theta = 360° = 2\pi$ radians, where $P_o = r + l = P_o$ maximum again, and $\alpha = 0$ again. The cycle for one vane is then completed and will be repeated.

All of the vanes **32, 33, 34, 35, 36, 37, 38** undergo the same cycle as the vane **31**. If there are n vanes, they may be placed $2\pi/n$ radians apart, so that there will be equal working spaces between vanes.

The surface which the vane tips circumscribe as they rotate and oscillate about the hub shaft can be derived mathemetically; they can be written in polar coordinates with the origin at the centerline of the hub-shaft **11**. For a prescribed design, the only variable is the angle θ. The angle θ is zero when a radial line drawn from the centerline of the drum first passes through the centerline of the hub shaft then through the pivot point of the vane and through the centerline of the vane. The vane is in its straight line extended position at $\theta =$ zero and $P_o = r_1 + l_1$, which is at its largest radius.

The fixed parameters for a prescribed design are:

c = the distance between the centerlines of the drum and the hub shaft.

h = the width of the slot in which the vane reciprocates and oscillates.

l = the length of the vane from its pivot point to its extended position.

r **32** the radial distance from the hub centerline to the vane pivot point, and

R = the radius of the drum where the drum bears on the vane.

The variable parameters are:

e = the distance from the vane pivot point to its slot bearing point at R.

t = the thickness of the vane at e.

P_o = the radius from the hub centerline to the vane tip.

θ = the angle of the hub and drum measured from the radial line drawn from the drum centerline to the centerline of the hub shaft.

The equation for the radius of the circumscribed surface of the vane tip with its origin at the hub centerline is:

$$P_0=\sqrt{r^2+l^2+2rl\sqrt{1.0-\frac{c^2\sin^2\theta}{(R-r)^2+2c(R-r)\cos\theta+c^2}}}$$

The equation for the distance from the vane pivot point to the point where the drum bears on the drum is:

$$e=\sqrt{(R-r)^2-2(R-r)\,c\cos\theta+c^2}$$

The equation for the thickness of the vane is

$$t=h\cos\{\sin^{-1}[c\sin\theta/\sqrt{(R-r)^2-2c(R-r)\cos\theta+c^2}]\}$$

These equations may be derived as follows:

The distance s between the parallel radial lines R and r at angle θ:

$$s=c\sin\theta. \tag{1}$$

The chord segment distance a for the vane contact at radius R to the vane pivot point at r :

$$a=(R-r)\sin\theta \tag{2}$$

The maximum distance b from the vane pivot point to the chord, a line normal to the chord:

$$b=(R-r)\cos\theta-c \tag{3}$$

The hypotunuse e of the triangle abe :

$$e^2=a^2+b^2=(R-r)^2(\sin^2\theta+\cos^2\theta)-2(R-r)\,c\cos\theta+c^2$$

$$e=\sqrt{(R-r)^2-2(R-r)\,c\cos\theta+c^2} \tag{4}$$

This gives the second equation shown above.

The sine of the angle α between the radial line r and the vane centerline l:

$$\sin\alpha=s/e$$

$$=c\sin\theta/\sqrt{(R-r)^2-2(R-r)\,c\cos\theta+c^2} \tag{5}$$

The cosine law is used to get the radius of curvature P_1 of the surface circumscribed by the vane with respect to the star shaft centerline.

$$\cos\alpha=\sqrt{1-\sin^2\alpha}$$

$$P_o^2=r^2+l^2-2rl\cos(\pi-\alpha)$$

$$=r^2+l^2+2rl\cos\alpha$$

$$P_0=\sqrt{r^2+l^2+2rl\sqrt{1.0-\frac{c^2\sin^2\theta}{(R-r)^2+2c(R-r)\cos\theta+c^2}}} \tag{6}$$

which is the first equation given above.

The angle β between the vane and the radial line R :

$$\sin\beta=s/e=c\sin\theta/\sqrt{(R-r)^2-2c(R-r)\cos\theta+c^2} \tag{7}$$

For a constant slot h in the drum at radius R , to determine the vane thickness t with respect to the distance e from the vane pivot point, so that it will fit snugly in h :

$$t=h\cos\beta$$

$$=h\cos\{\sin^{-1}[c\sin\theta/\sqrt{(R-r)^2-2c(R-r)\cos\theta+c^2}]\} \tag{8}$$

For the radius of curvature of the drum circle with respect to the centerline of the star shaft center, the cosine law is again used:

$$P_i=\sqrt{R^2+c^2-2Rc\cos\theta} \tag{9}$$

The angle ϕ between the radial line P and the centerline to the vane l is obtained by the sine law.

$$r/\sin\phi=P_o/\sin(\pi-\alpha)$$

$$=P_o/\sin\alpha$$

$$\sin\phi=r/P_o\sin\alpha$$

The area A_1 at θ_x:

$$A\approx\tfrac{1}{2}(l-e_x)^2(r/P_o)\sin\alpha_x[1-(r/P_o)\sin\alpha_x\tan\alpha_x] \tag{10}$$

The area A_w of the working space for n vanes of constant thickness t :

$$\theta_x=\theta_x+(2\pi/n) \tag{11}$$

$$A_w=\left\{1/2\int_{\theta_x}^{\theta_x+\frac{2\pi}{n}}(P_0^2-P_i^2)d\theta-lt-\frac{t}{2}(e_x+e_{x1})\right.$$

$$+1/2(l-e_x)^2\frac{r}{P}\sin\alpha_1\left[1-\left(\frac{r}{P_{0x}}\right)\sin\alpha_x\tan\alpha_x\right]$$

$$\left.-1/2(l-P_{x_1})^2\frac{r}{P_{0x}}\sin\alpha_2\left[1-\left(\frac{r}{P_{0x1}}\right)\sin\alpha_{x^1}\tan\alpha_{x^1}\right]\right\} \tag{12}$$

The working space or working volume is V_w = the working area times the width of the vane s.

$$V_w=A_wS \tag{13}$$

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. A vane device for use as an engine, a compressor, or a motor, comprising

a rotating central hub having a series of vane pivot points spaced therearound at equal radii from the center of the hub,

at least three vanes, each pinned at its center of gravity to said hub at a said pivot point,

a generally cylindrical drum with its axis parallel to and displaced radially from that of said hub, said drum having a separate slot for each vane through which the vane extends, for guiding the radial position of each said vane,

synchronizing means mechanically linking said hub and said drum so that they rotate in the same direction and at the same rotating speed, so that said vanes reciprocate and oscillate in said guide slots as the hub and drum rotate,

a housing enclosing said vanes and cooperating with said vanes and said drum to provide a series of working spaces, one for each said vane to compress or expand a fluid, and

intake and exhaust port means for leading fluid into and from said working spaces.

2. The device of claim 1 as applied to a vane compressor, wherein said intake port means is substantially diametrically opposite said exhaust port means, said intake port means leading into a working space and being closed by a said vane just after the working space for said vane is at its largest volume, low pressure gas being compressed as the working space is made smaller, the compressed gas being discharged through said exhaust port means after it has been compressed to a desired pressure level; said exhaust port means being passed by said vane just before the working space of that said vane is at its smallest volume, the compressed gas which is trapped in said smallest volume working spaces being expanded to do work on the vanes until its pressure is substantially equal to the intake gas pressure as said vanes move to open said intake port means.

3. The device of claim 1 operated as a vane motor wherein said intake port means is substantially opposite said exhaust port means and each said vane opens a said working space to said intake port means just after said working space passes its smallest volume, said intake port means remaining open until the space between said vanes is at a prescribed value, then the next said vane moving to close said working space off from said intake port means and to trap compressed gas in said working space, said working space increasing in volume and said compressed gas expanding to do work on the vanes and hub until said working space is near its largest volume, then said working space being opened by a said vane to the exhaust port means, so that said expanded gases are exhausted; said working space remaining open to said exhaust port means until said working space has been reduced to where the low pressure exhaust gases may be compressed to the high pressure intake pressure just when the space between the vanes is the smallest.

4. The device of claim 3 having an adjustable cutoff port means for varying the amount of compressed gas that is expanded in the motor, by adjusting the prescribed intake working space.

5. The device of claim 1 operated as an engine, said intake and exhaust port means being a single port, said device having

said port being opened to said said working space approximately where said space attains its largest volume,

a fuel injector and a spark ignition system,

a fan for scavenging said port and forcing a fresh charge of air into said port, each said vane moving trap a fresh charge in each said working space,

means for injecting fuel into said trapped air, so that said air and fuel are compressed as said motor moves to reduce the working space between adjacent said vanes,

said spark ignition system acting just after each said working space attains its smallest volume to explode fuel in that said space to heat it by a constant volume combustion process, thus increasing its pressure, said hot compressed gases acting on the associated vane to turn the hub, so that said working space increases and said gases expand and do work on said hub until just before said working space attains its largest volume, when said vanes open it to the port and the centrifugal force of the hot gases forces them to flow out radially while the fan forces them to flow axially.

6. A rotary vane device comprising

a circular drum,

a central hub shaft,

a series of radially directed vanes each pinned at its respective center of gravity to equally spaced axial hinges on said central hub, which thereby supports their full centrifugal pull,

synchronizing means,

a housing having intake and exhaust port means,

said drum having equally spaced axial slots, one for each vane, and having axial beam segments, one between each adjacent pair of said slots, said drum also having disc sections at each end to support said beams and to carry bearings for said drum, said vanes fitting tightly in said slots for reciprocation and oscillation therein;

said central hub and said drum being mechanically joined by said synchronizing means so that they rotate in the same direction and at the same rotating speed,

the center of rotation of said central hub shaft being displaced radially by an amount "c" from the center of rotation of said drum so that said vanes reciprocate and oscillate in said slots as said drum rotates, said vane tips circumscribing a cylindrical surface;

said radial displacement "c" being such that said vane tips lie near said slots at their most radially inward positions and when the vanes are rotated 180° from their inward position they are at their maximum radially outward position,

said housing enclosing said vanes with a very small working clearance between the vane tips and a cylindrical surface of said housing,

the space between adjacent vanes and the housing and drum surfaces between said vanes constituting the working spaces of said device,

the working space for any two adjacent vanes being the largest when a radial inward center line between those said adjacent vanes first goes through said hub center line then through said drum center line, said working space between any two said vanes being the smallest when a radial inward center line between its said vanes first goes through said drum center line then through said hub center line.

7. The device of claim 6 wherein the thickness of each said vane varies over its length, fitting snugly in its said drum slot as it reciprocates and oscillates in said slot.

8. A vane device for use as an engine, a compressor, or a motor, comprising

a central hub,

at least three vanes pinned to said hub,

a generally cylindrical drum with its axis parallel to and displaced radially from that of said hub, said drum having a slot for each vane through which the vane extends, for guiding the radial position of each said vane,

synchronizing means comprising a gear train with pitch diameters such that said hub shaft and drum rotate in the same direction and at the same rotating speed, so that said vanes reciprocate and oscillate in said guide slots as the hub and drum rotate,

a housing enclosing said vanes and cooperating with said vanes and said drum to provide a series of working spaces, one for each said vane to compress or expand a fluid, and

intake and exhaust port means for leading fluid into and from said working spaces.

9. A rotary vane mechanism, comprising

a drum of radius R, having at least one slot,

a hub inside said drum, with its centerline displaced a displace c from the centerline of said drum,

at least one pivot point located on said hub at radius *r* from the centerline of said hub,

a vane of length 1 pinned at each said pivot point, each said vane passing through and bearing snugly on a said slot in said drum at said radius R from the centerline of said drum,

synchronizing means for causing said drum and said hub to rotate at the same speed and in the same direction,

the tip of said vane circumscribing a curved surface, the radius P_o of said curved surface in reference to the hub centerline being, in terms of the angle θ which the radial line *r* makes as the mechanism rotates, and in terms of polar coordinates with the origin at the hub centerline:

$$P_0=\sqrt{r^2+l^2+2rl\sqrt{1.0-\frac{c^2\sin^2\theta}{(R+r)^2+2c(R-r)\cos\theta+c^2}}}$$

10. The mechanism of claim 9 wherein the distance *e* from said pivot point to said bearing point in said slot is

$$e=\sqrt{(R-r)^2-2(R-r)\,c\cos\theta+c^2}$$

11. The mechanism of claim 9 wherein each said slot has a constant thickness *h* and its vane has a variable thickness *t* over its length, so that it fits snugly in said slot as it reciprocates and oscillates in said slot.

12. The mechanism of claim 11 wherein

$$t=h\cos\{\sin^{-1}[c\sin\theta/\sqrt{(R-r)^2-2c(R-r)\cos\theta+c^2}]\}$$

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