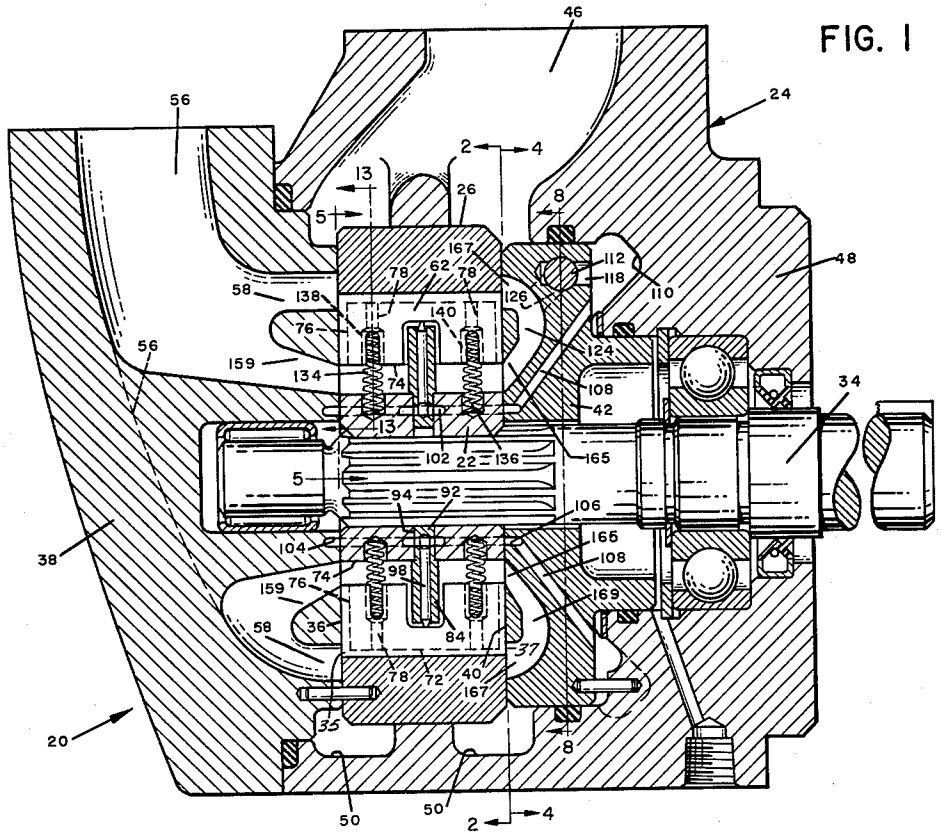
June 28, 1966 C. E. ADAMS ETAL 3,257,958

ROTARY VANE FLUID POWER UNIT

Original Filed Sept. 14, 1962 4 Sheets-Sheet 1

FIG. 1



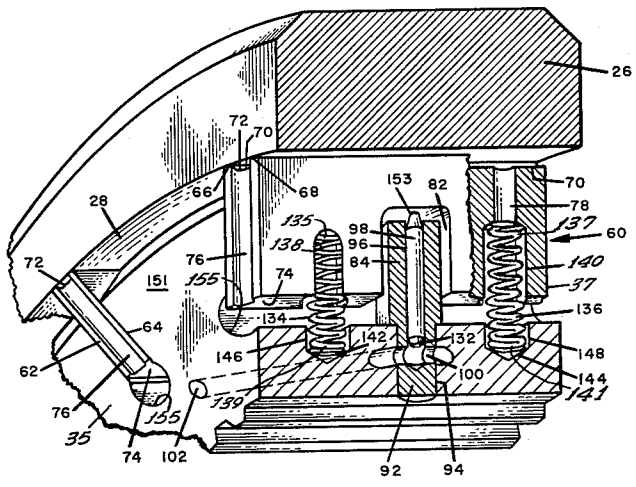


FIG. 5

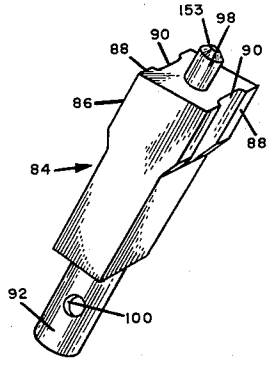


FIG. 6

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ROTARY VANE FLUID POWER UNIT

Original Filed Sept. 14, 1962 4 Sheets-Sheet 2

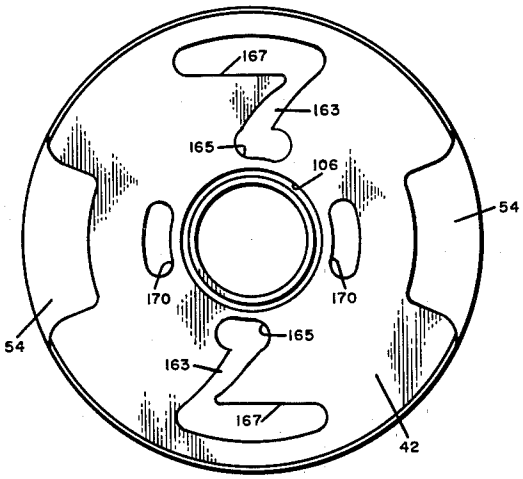


FIG. 4

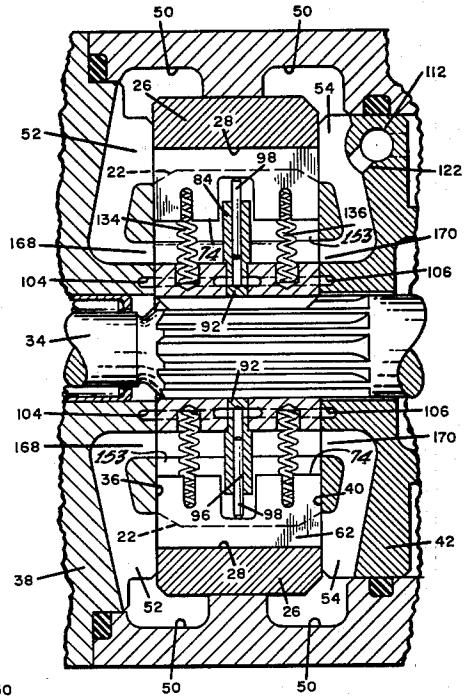


FIG. 3

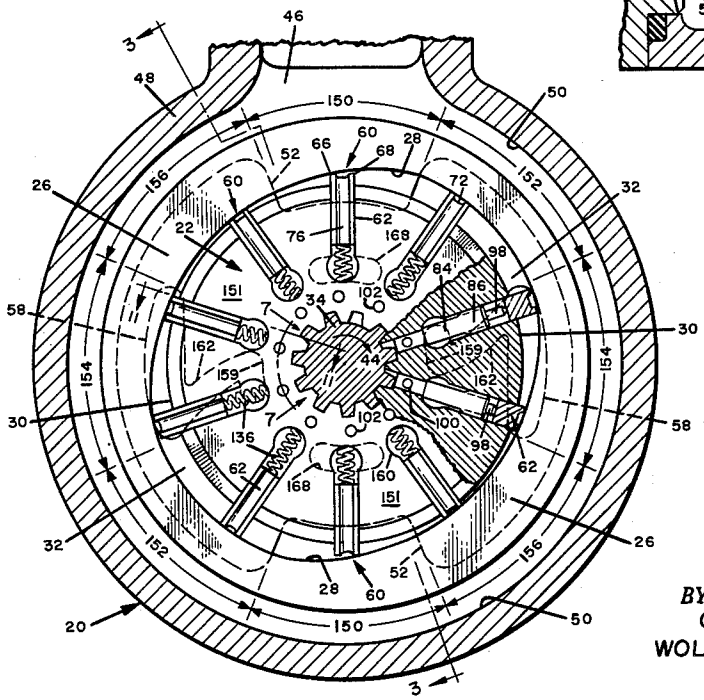


FIG. 2

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ROTARY VANE FLUID POWER UNIT

Original Filed Sept. 14, 1962 4 Sheets-Sheet 3

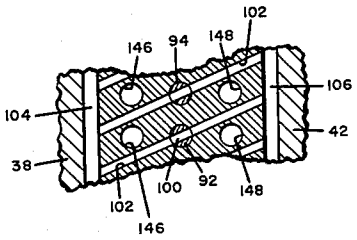


FIG. 7

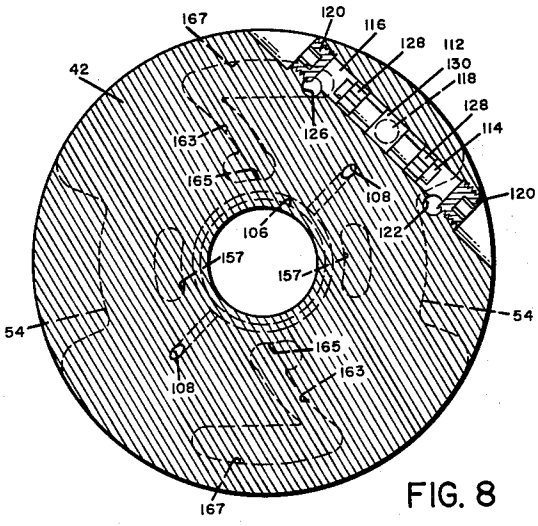


FIG. 8

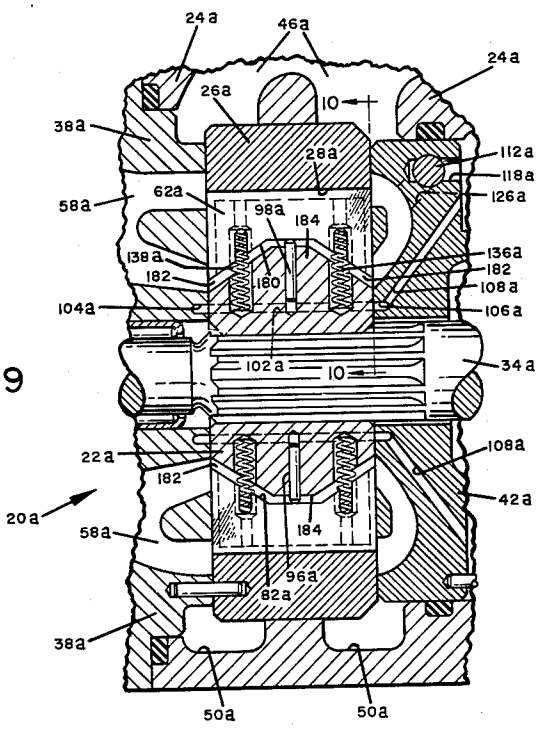


FIG. 9

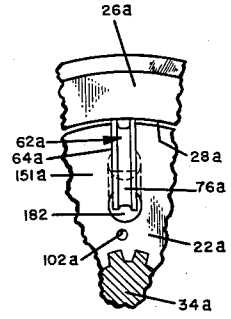


FIG. 10

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ROTARY VANE FLUID POWER UNIT

Original Filed Sept. 14, 1962 4 Sheets-Sheet 4

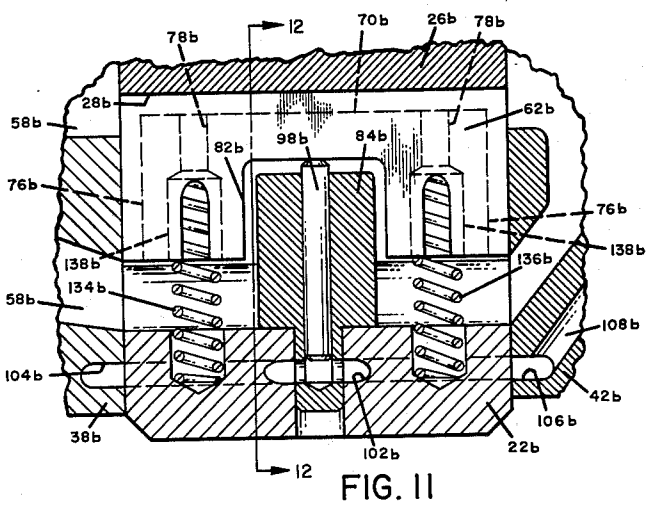


FIG. 11

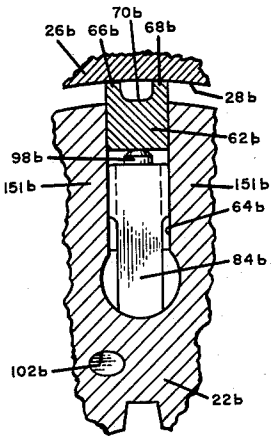


FIG. 12

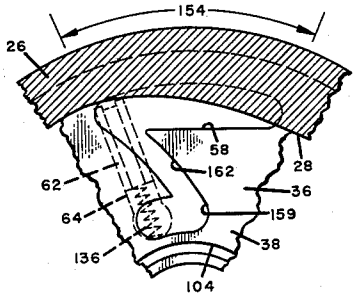


FIG. 13

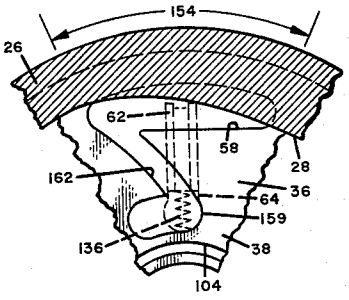


FIG. 14

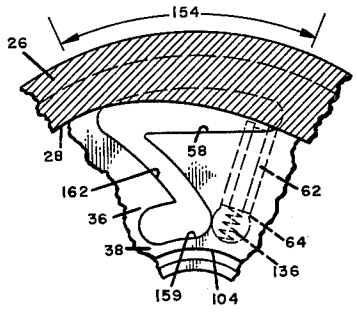


FIG. 15

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United States Patent Office 3,257,958 Patented June 28, 1966

3,257,958

ROTARY VANE FLUID POWER UNIT

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Continuation of application Ser. No. 223,748, Sept. 14, 1962. This application Mar. 29, 1965, Ser. No. 445,855
26 Claims. (Cl. 103—136)

The present application is a continuation of applicants' copending application Serial No. 223,748, filed September 14, 1962, now abandoned.

The present invention relates to rotary vane pumps and motors, which for convenience will be referred to generally as rotary vane "fluid power units." A fluid power unit of this character is disclosed in United States Patent No. 2,832,293, issued April 29, 1958, to one of the applicants of the present application and Yung Ho Sun.

As compared to other types of pumps and motors, rotary vane pumps and motors characteristically afford advantages including relatively low initial cost of manufacture and relatively small physical size. However, the performance capabilities now being sought from vane pumps and motors have greatly increased the significance of limitations and shortcomings inherent in conventional pumps and motors of this type. The capabilities being sought in rotary vane fluid power units include lengthened durability or service life, capacity to work efficiently and dependably against very high fluid pressures, and the capability of operating efficiently and dependably over a widespread speed range including very high operating speeds.

One object of the invention is to provide a rotary vane fluid power unit having a new and improved construction which materially increases the performance capabilities of the unit, while at the same time minimizing the physical size of the unit.

Another object is to provide an improved rotary vane fluid power unit having a novel construction which minimizes to advantage the size of the unit, while at the same time providing an advantageous capability of the unit to operate against very high fluid pressures with efficiency and dependability over a long service life of the unit.

Another object is to provide a rotary vane fluid power unit in which effective sealing engagement of the vanes with a coacting cam surface is obtained by a new and improved construction which assures that each vane is continuously urged outwardly by a force that is effective, yet not excessive.

Another object is to provide a rotary vane fluid power unit having an improved construction which assures that each vane is continuously urged outwardly, while at the same time serving during operation of the unit to effect through fluid pressure a cyclic increase in the outward force on the vane, which cyclic increase in force is automatically synchronized to advantage with progress of the vane along a coacting cam surface.

Another object is to provide a rotary vane power unit of the above character in which high performance capabilities are achieved in a unit of significantly minimized size by virtue of an improved construction which at once (1) effects an application to each vane by fluid pressure of a highly advantageous outward force, (2) provides to eacn vane very extensive support from a rotor of minimized size, and (3) produces great strength in the vane supporting rotor structure, while at the same time effectively minimizing the size of the rotor.

Another object is to provide an improved rotary vane fluid power unit in which the vanes are forced outwardly by fluid pressure energized structure which affords a highly

advantageous mutual reinforcement of portions of the rotor which slidably support the vane.

Another object is to provide an improved rotary vane fluid power unit in which the vanes are urged toward a coacting cam surface to great advantage by the cumulative action of springs and the forces of fluid pressure.

Another object is to provide a rotary vane pump in which the outward force, which must be applied to individual vanes moving through a fluid intake zone in the pump in order to maintain engagement of the vanes with the coacting cam surface when the pump is operated at high speeds, is minimized to great advantage by an improved shaping of the vane slots and vanes that materially accelerates the flow of incoming fluid into the inner portions of the vane slots while at the same time advantageously minimizing the size of the fluid flow passages required within the pump rotor for supplying fluid to the inner portions of the slots.

Another object is to provide a rotary vane pump having high speed operational capabilities that are materially enhanced by virtue of an improved shaping of the vanes which in effect serves to centrifugally "pump" incoming fluid into the vane slots inwardly of the vanes as the vanes move outwardly in passing through a fluid intake zone in the pump.

Another object is to provide a rotary vane fluid power unit in which maintenance of optimum pressure contact with the coacting cam surface or track of vanes moving through and beyond a fluid discharge zone in the unit is aided to great advantage by an improved control of the discharge of fluid from the vane slots.

Another object is to provide a rotary vane fluid power unit in which an improved control of the discharge of fluid from the vane slots is provided and utilized to achieve at once a highly advantageous reduction of fluid resistance to inward acceleration and inward movement of vanes moving through a fluid discharge zone within the unit and an equally advantageous deceleration by fluid of inwardly motion of vanes passing from the fluid discharge zone to an adjacent sealing zone within the unit.

Another object is to provide an improved rotary vane fluid power unit as recited in the preceding object in which the reduction of fluid resistance to inward movement of the vanes is coordinated with the rotary motion of the vanes to maintain optimum pressure contact with the cam surface of vanes entering into a fluid discharge zone within the unit.

Another object is to provide a rotary vane fluid power unit or pump of the character recited in the preceding objects which is capable of serving as either a pump or a motor.

Another object is to provide a rotary vane fluid power unit of the character recited in the preceding objects, which is inherently well adapted for economical manufacture.

Other objects and advantages will become apparent from the following description of the exemplary embodiments of the invention illustrated in the accompanying drawings, in which:

FIGURE 1 is an axial sectional view of a rotary vane fluid power unit embodying the invention;

FIG. 2 is a transverse sectional view, taken along the line 2—2 of FIG. 1, and showing the cam ring, a segment of the housing and the high pressure porting in the latter rotated ninety degrees;

FIG. 3 is an axial sectional view, taken along the line 3—3 of FIG. 2;

FIG. 4 is a face view of the pressure or cheek plate, taken with reference to the line 4—4 of FIG. 1;

FIG. 5 is a fragmentary perspective view, taken generally with reference to the line 5—5 of FIG. 1;

FIG. 6 is a perspective view on an enlarged scale of a vane actuating rotor reinforcing element associated with each vane;

FIG. 7 is a fragmentary sectional view taken along the arcuate line 7—7 of FIG. 2 and showing fluid supply passages in the rotor for energizing fluid actuating elements for the respective vanes;

FIG. 8 is a sectional view taken along the line 8—8 of FIG. 1 and showing valve means used to supply operating fluid to the fluid actuating elements for the vanes from the connecting passage under a higher fluid pressure;

FIG. 9 is an axial sectional view similar to the central portion of FIG. 1 but showing a modified construction of the unit;

FIG. 10 is a fragmentary sectional view taken along the line 10—10 of FIG. 9;

FIG. 11 is a fragmentary sectional view on an enlarged scale taken with reference to the line 11—11 of FIG. 2, but showing a slight modification of the structure used in the unit of FIGS. 1 to 8;

FIG. 12 is a fragmentary sectional view taken along the line 12—12 of FIG. 11;

FIG. 13 is a fragmentary sectional view taken with reference to the line 13—13 of FIG. 1 but illustrating in phantom the relationship of one end of a typical vane and vane slot to adjacent outlet port structure as the vane moves into one fluid discharge zone;

FIG. 14 is a view similar to FIG. 13 but illustrating a later phase in the movement of the vane and slot through the fluid discharge zone in which the inner portion of the slot is fully alined with the adjacent port structure; and

FIG. 15 is a view similar to FIG. 14 but illustrating a still later phase in the progress of the vane and slot through the fluid discharge zone in which the inner portion of the slot is displaced beyond the adjacent port structure.

Referring to the drawings in greater detail, the pump 20 forming the embodiment of the invention illustrated in FIGS. 1 to 8 comprises a rotor 22 encased within a pump housing 24 which includes, as shown, a cam ring 26 encircling the rotor. The inner periphery of the cam ring 26 defines a cam surface 28 encircling the periphery 30 of the rotor, and being shaped and positioned to define with the outer periphery of the rotor two arcuate spaces 32 for fluid located generally on diametrically opposite sides of the rotor, FIG. 2.

The two opposed spaces 32 constitute in the pump 20 pumping spaces for fluid. The two spaces 32 are not necessarily discontinuous, since the space between the cam surface 28 and the rotor periphery 30 extends all the way around the rotor. However, the spacing between the cam surface 28 and the rotor periphery 30 narrows between the two pumping spaces 32 to the extent that these spaces may here be regarded as being discontinuous.

It will be understood that the pump 20 is a balanced pump and that the forces on the rotor of fluid under pressure within the opposed spaces 32 are largely balanced.

The rotor 22 is supported and driven by a splined drive shaft 34 journalled in the housing 24. As shown best in FIG. 1, opposite ends of the rotor 22 define and are bounded by two flat end faces or surfaces 35, 37. One end face 35 of the rotor 22 has a running fit with a ported annular surface 36 on a segment 38 of the housing 24. The opposite end face 37 of the rotor 22 has a running fit with a ported surface 40 of a floating pressure or cheek plate 42, which is urged axially against the rotor by fluid under pressure, as will presently appear.

In this instance, the rotor 22 turns clockwise as viewed in FIG. 2, and as indicated by the arrow 44. The fluid intake or suction end of each of the pumping spaces 32 (the counterclockwise end as viewed in FIG. 2) is connected to an inlet or suction passageway 46 formed in the section 48 of the pump housing 24. As shown in FIGS. 1, 2 and 3, the intake passageway 46 connects with two annular passages 50 formed in the housing 24 in generally encircling relation to the cam ring 26. The two passages 50 communicate continuously with the intake end of each pumping space 32 through two intake ports 52, 54 formed in the housing section 38 and cheek plate 42 for each space 32, as shown in FIG. 3, and communicating at opposite end of the rotor with the intake end of the adjacent pumping space 32.

The opposite or discharge ends of the pumping spaces 32 (the clockwise ends with reference to FIG. 2) are connected continuously to an outlet or discharge passageway 56 formed in the housing section 38, FIG. 1. As shown the outlet passageway 56 communicates with the outlet ends of the pumping or working spaces 32 through ports 58 opening through the rotor confronting face 36 in the housing section 38, FIG. 1, in circumferentially spaced relation to the intake ports 52 and 54 communicating with the inlet ends of the spaces 32, FIGS. 2 and 3.

The rotor 22 carries an annular series of vane units 60, FIGS. 1, 2 and 5, which operate upon rotation of the rotor to move fluid through each of the pumping spaces 32 from the associated intake ports 52, 54 to the coacting discharge port 58.

Each vane unit 60 comprises a flat vane 62 slidably disposed within a coacting slot 64 in the rotor 22. Each slot 64 extends between opposite ends of the rotor 22 and opens outwardly through the periphery of the rotor to allow the coacting vane 62 to project outwardly into sliding engagement with the cam surface 28.

As shown, the outer end of each vane 62 defines two spaced parallel edges 66, 68, one or both of which are caused to continuously engage the cam surface 28. The outer end of each vane is subject to exposure to the pressure of fluid in the interspace adjacent the vane between the periphery of the rotor and the encircling cam surface 28. In this instance, the outer end of each vane 62 defines a surface 70 located between the sealing edges 66 and 68. The force of fluid pressure on the surface 70 tends to urge the vane inwardly. As shown, the surface 70 on the outer end of each vane is recessed inwardly of the adjacent sealing edges 66, 68 to define a groove 72 extending the full axial length of the vane.

Effective sealing engagement of each vane 62 with the cam surface 28 is assured continuously by the cumulative action on the vane of the outward force of fluid pressure on the inner edge of the vane, the outward force of spring pressure applied to the vane, and the outward force of fluid under a high pressure continuously applied to a high pressure vane biasing area associated with each vane and isolated from direct communication with the inner edge of the vane, as will be described. Moreover, each vane unit 60 has a construction which provides the desired outward biasing forces for a coacting vane, while at the same time providing extensive and highly efficient support to the vane and affording a highly effective reinforcement of the rotor structure which supports the vane.

As shown in FIGS. 1 and 5, the inner edge of each vane defines a second biasing surface 74 extending across the full axial length of the vane. Fluid pressure applied to the surface 74 acts to urge the vane outwardly, as previously intimated.

The space between the inner edge surface 74 of each vane and the bottom of the coacting vane slot 64 is continuously connected to communicate with the first surface 70 on the outer edge of the vane. The two ends of each vane 62 at the ends of the rotor 22 are medially grooved to define medial channels 76 connecting opposite ends of the outer vane groove 72 with the inner vane surface 74. Also, two spaced parallel bores 78 are machined

in each vane 62 to extend inwardly through the vane from the outer groove 72 to the inner surface 74.

The third force of fluid pressure acting on each vane is produced by structure which extends outwardly in the coacting vane slot an extensive distance outwardly beyond the inner extremity of the vane.

As shown in FIGS. 2, 3 and 5, each vane is shaped to define a central notch 82 of substantial width extending between opposite sides of the vane and extending outwardly from the inner extremity of the vane for a very substantial distance. As illustrated, each notch 82 has a radial depth, measured from the inner extremity of the vane to the bottom of the notch, which is somewhat greater than one-half the corresponding total radial dimension of the vane from the inner to the outer radial extremities of the vane. Also, each vane notch 82 has substantial width measured axially with respect to the rotor.

Each vane notch 82 accommodates a central plug 84 which is machined separately from the rotor 22. A typical plug 84 is illustrated in perspective in FIG. 6, and has a form which is adapted to be manufactured economically with precision.

As shown, each plug 84 has a relatively wide outer portion 86 adapted to fit firmly within the coacting slot 64 and provide mutual reinforcement to adjacent portions of the rotor defining opposite sides of the slot. The two opposite rotor engaging faces 88, FIG. 6, of the plug segment or portion 86 are designed to fit firmly against the opposing sides of the coacting slot. Preferably, a medial, generally radial groove 90 is formed in each face 88 of each plug to facilitate insertion of the plug into a coacting vane slot in the rotor. This construction of the plugs makes for economy of manufacture while at the same time affording a close fitting relationship of the plugs and rotor so that optimum reinforcement is provided to the rotor by the plugs.

The inner end of each plug 84 defines a cylindrical projection 92 designed to fit into a cylindrical bore 94 extending into the rotor 22 from the bottom of the coacting slot 64, as shown in FIGS. 1, 2 and 3.

Each plug 84 is centrally bored longitudinally from the outer end of the plug to define an outwardly open cylinder 96, FIG. 5, which stops short of the extreme inner end of the plug. The cylinder 96 receives a freely movable yet close fitting plunger 98 having a tapered outer end extending beyond the plug and adapted to engage the inner edge of the coacting vane 62 at the bottom of the notch 82.

A transverse bore 100 formed in the cylindrical projection 92 of each plug 84 intersects the plug cylinder 96 inwardly of the plunger 98 and connects with an oblique bore 102 formed in the rotor 22 and extending between opposite end faces of the rotor at an angle to the axis of the rotor, as illustrated in FIGS. 1, 5 and 7. An annular series of bores 102 are drilled in the rotor 22 inwardly of the slots 64 for feeding high pressure fluid to the cylinders in the respective plugs.

Opposite ends of the high pressure bores 102 continuously communicate with annular grooves 104, 106 formed in the opposing faces of the housing section 38 and cheek plate 42.

The annular groove 106 in the cheek plate 42 is connected through bores 108, FIG. 1, with an annular pressure space 110 defined between the end of the cheek plate 42 opposite from the rotor 22 and the housing section 38. The annular pressure space 110 is continuously connected with the high pressure end of one of the pumping spaces 32 by means of an automatic spool valve 112, FIGS. 1, 3 and 8.

As shown, the spool valve 112 comprises a valve spool 114 slidably mounted in a chordal bore 116 in the pressure or cheek plate 42. An axial bore 118 in the cheek plate extends from the space 110 to intersect the center of the bore 116. Opposite ends of the bore 116 are stoppered by threaded plugs 120. A port 122 in the plate 42 connects one end of the bore 116 with an intake port 54, FIGS. 3 and 9, for the working space 32 which supplies fluid to the pressure space 110. The other end of the same working space 32 is connected through a passage 124 in the cheek plate 42, FIG. 1, and a bore 126 with the end of the bore 116 opposite the bore 122.

Two flatted enlargements 128 on the spool 114 engage the bore 116 to guide the spool. A central enlargement 130 on the spool 114 slidably engages the bore 116 and forms a seal between the bores 122, 126, whereby the spool 114 automatically moves to the low pressure end of the bore 116 to connect the pressure space 110 with the high pressure end of the bore 116 and hence with the high pressure end of the connected working space 32.

This construction provides an extended versatility in the use of the illustrated pump 20, in that the pump can be reversed, if so desired, to receive fluid through the passageway 56, and to discharge fluid through the passageway 46. Also, the same structure can be used as a fluid motor in which operating fluid is supplied under pressure to either of the passageways 46, 56 and discharged through the other of the passageways 46, 56. For any of these modes of operation, the valve 112 automatically supplies fluid from the high pressure end of the connected working space 32 to the space 110 where it acts to urge the pressure or cheek plate 42 axially against the rotor 22. This same high pressure fluid is connected through the bores 108, 102 and 100 to the inner ends of the plug cylinders 96, as described, where this high pressure fluid acts on the inner end of each plunger 98 to urge the coacting vane 62 outwardly, as described. Thus, the inner end of each plunger 98 defines a third surface 132 on which high pressure fluid acts to urge the coacting vane outwardly.

As shown, outward spring force is continuously applied to each vane 62 by two helical compression springs 134, 136 disposed on opposite sides of the intervening plug 84, as shown in FIGS. 1, 3 and 5. The springs 134, 136 for each vane have outer, power applying ends 135, 137 extending into counterbores 138, 140 in the vane bores 78, FIG. 5. The springs 134, 136 are smaller in diameter than the counterbores 138, 140 and the power applying ends 135, 137 of the springs press against the outer ends of the counterbores 138, 140 for movement in and out with the vane. The inner ends 139, 141 of the springs 134, 136 rest on seats 142, 144 in shallow bores 146, 148 extending into the rotor 22 from the bottom of the coacting vane slot 64. Thus, the inner or support ends 139, 141 of the springs 134, 136 are stationary with respect to the rotor 22 with the result that the springs are flexed and store energy upon inward movement of the vane and subsequently release energy by relaxation to extend the vane.

All the forces applied to each vane 62 and tending to move the vane within the rotor slot operate cumulatively to assure continuous and effective engagement of the vane with the cam surface 28 under all operating conditions. In this connection it should be borne in mind that the outward force required to keep each vane in optimum engagement with the cam surface 28 varies as the vane progresses through its annular path or orbit.

As each vane 62 moves through the fluid intake end or zone 150 of each pumping space 32 the vane must move outwardly in its slot to maintain its contact with the cam surface. (For convenience in identification, the successive zones including the intake zones 150 within the pump through which a vane passes are denoted in FIG. 2 by the corresponding radial angles of the annular path of the vane.) Moreover, each vane must be moved radially outward in each intake zone at a speed that is commensurate with the rotary speed of the rotor. The force required to accelerate each vane radially outward sufficiently to maintain the vane in contact with the cam

surface as the vane moves through each intake zone increases as an exponential function of the rotary speed of the rotor **22** and for this reason can become very high as rotor speeds are increased to increase the output volume that can be obtained from a pump of any particular size.

In the pump described, the plunger **98** coacting with each vane provides for forcing the vane outwardly within each intake zone **150** a force which is very powerful in relation to the transverse area of the plunger by virtue of the fact that the inner end surface **132** of the plunger is continuously subjected to the high output pressure of the pump and the outer end of the plunger and the outer edge of the vane are exposed to the much lower pressure of fluid entering the intake zone. Thus, in the pump, each vane plunger **98** can make available for extending the coacting vane in an intake zone **150** a force which is far greater than the vane extending force that can be provided by a spring that can be accommodated within a similar space in the pump rotor. Moreover, the outward force of each plunger **98** does not decrease as the coacting vane moves outwardly. Consequently, the pump can be driven at high speeds to obtain high output capacity with assurance that vanes passing through the intake zones **150** are held in contact with the cam surface **28** by applied forces including those applied by the plungers **98**.

As previously intimated, the construction of the pump serves not only to maximize the efftctive output capacity of the pump, but also to minimize the size of the pump. In this connection, it is especially noteworthy that the structure which defines the plunger cylinders **96** extends radially out into the vane slots **64** a very substantial distance radially beyond the inner extremities of the slots and a substantial distance radially beyond the inner positions of the inner extremities of the vanes. Moreover, the plunger cylinder defining structure, i.e., the plugs **84** in the pump described; transmits forces between adjacent rotor sectors **151** intervening between and defining the rotor slots **64** to the end that these rotor sectors mutually reinforce each other in sustaining the reaction of the vanes on the rotor sectors. The reaction on each rotor sector **151** of the adjacent vanes changes as the vanes progress through their orbit. The strength which each rotor sector must have to withstand the reactions of the adjacent vanes is sharply reduced by the mutual reinforcement of the rotor sectors all of which are not loaded to the same degree at once.

As a consequence, the root diameter of the vane slots **64** can be markedly reduced. This permits a similar reduction in the overall diameter of the rotor without reducing the radial depth of the vane slots. This results in a very significant reduction in the overall size of the pump, while at the same time providing vane slots of extensive overall radial depth which accommodate vanes **62** that have overall radial dimensions sufficient to enable the vanes to project individually a very extensive distance beyond the rotor, while at the same time providing optimum support to the vanes against high fluid pressures. The fact that the medial inner portions of the vanes **62** are cut away to accommodate the plunger cylinder defining structure which provides the desired reinforcement of the rotor sectors **151** does not significantly weaken the vanes or materially reduce the support provided to the vanes, since the overall radial dimensions of the vanes are not reduced.

Having reference to the construction of the rotor **22** as illustrated in the drawings, it will be appreciated that the construction of the rotor itself, apart from the reinforcing plugs **84**, is designed to maximize the bending strength of the individual rotor sectors **151** intervening between the vane slots **64**. Except as they are mutually reinforced by the intervening plugs **84**, the individual rotor sectors **151** have the structural form of cantilevering arms circumferentially spaced apart. The forces applied by the vanes **62** to the rotor sectors **151** are sustained by the bending strength of the sectors **151**.

In keeping with established design principles used in the construction of high pressure, high performance vane pumps, the rotor sectors **151** intervening between the vane slots **64** are designed and constructed as illustrated in the drawings to maximize the bending strength of the rotor sectors. In this connection it is noteworthy that the forces transmitted by the vanes **62** to the rotor sectors **151** produce in the rotor sectors **151** bending moments that tend to increase toward the inner or base ends of the rotor sectors. Moreover the circumferential width of each rotor sector **151** decreases in an inward direction on account of the inwardly converging orientation of the slots **64**. Consequently the applied bending stress on the rotor sectors **151** tends to increase in an inward direction.

The rotor sectors **151** constructed as shown in the drawings are designed to provide within the axial limits of the rotor **22** and within the circumferential width limitations on the rotor sectors **151**, the maximum effective bending strength for the rotor sectors **151**.

As shown in the drawings, FIGS. 1 and 5, opposite axial ends of each rotor sectors **151** are flush with the flat rotor end faces **35, 37** and form portions of the end faces **35, 37**. Each individual vane **62** has an axial length equal to the axial spacing between the rotor end faces **35, 37** and is flush at its axial ends with the rotor faces **35, 37**.

It will be evident from the foregoing observations that the bending stress on the individual rotor sectors **151** is greatest on the inner portions of the rotor sectors, particularly on the portions **153**, FIG. 3, of the rotor sectors **151** that extend inwardly from the radial positions occupied by the inner edges **74** of the two adjacent vanes **62** when the vanes are fully extended. Having reference again to the drawings, it will be noted that each rotor sector portion **153** has a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane **62** that extends outwardly from the periphery of the rotor when the vane is fully extended, the flat end faces **35, 37** of the rotor extending across opposite ends of each rotor sector portion **153** and being flush with opposite ends of each adjacent vane **62**. Moreover, the portion **153** of each rotor sector **151** located radially inward of the radial positions of the inner edges **74** of the fully extended adjacent vanes is of solid construction, as shown, that is impervious to the passage of fluid therethrough between the adjacent slots **64**. The solid construction of the rotor sector portions **153**, extending the full axial width of the portions of the vanes **62** that project from the periphery of the rotor, serves to maximize the bending strength of the rotor sectors **151** while at the same time being impervious to the passage of fluid through the rotor sector portions **153** between the adjacent slots **64**.

It is noteworthy at this point that rounding out of the bottoms of the vane slots **62** to form at the bottoms of the vane slots the transversely extending concave surfaces **155**, identified in FIG. 5, increases the bending strength of the rotor sectors **151** by avoiding stress concentrations at the bottoms of the slots.

The mutual reinforcement of the rotor sectors **151** gained by means of the intervening plugs **84** as described magnifies the inherent strength of the rotor sectors, solidly constructed as illustrated, to provide the powerful resistance to deflection of the rotor sectors that permits minimization of the size of the rotor **22** and radial deepening of the vane slots **64** to maximize the performance to size relationship of the unit as previously indicated.

The two compression springs **134, 136** associated with each vane **62** apply continuous outward forces to the vane which act cumulatively with the outward force of

the associated vane plunger **98** to move the vane outwardly in continuous contact with the cam surface **28** as the vane passes through each fluid intake zone **150** as described. However, the forces of the springs **134, 136** on each vane are not necessarily sufficient of themselves to maintain engagement of the vane with the cam surface **28** when the pump is operated at very high pressures.

The two springs **134, 136** and the high pressure plunger **98** associated with each vane **62** continue to act cumulatively to urge the vane outwardly into effective sealing engagement with the cam surface **28** as the vane passes from each fluid inlet zone **150** through a fluid transfer zone **152**, FIG. 2, to the adjacent fluid outlet zone **154**.

While the description of the forces acting on the vanes moving through the fluid intake zones **150** and the fluid transfer zones **152** has been focused on the outward forces applied to each vane by the coacting springs **134, 136** and the coacting high pressure plunger **98**, it is necessary to bear in mind that these are not the only forces acting radially on the vanes. As previously intimated, each vane is continuously subjected to the outward force of fluid pressure acting on the inner edge surface **74** of the vane and to the inward force of pressure acting on the outer edge surface **70** of the vane. In a general way, the inward and outward forces of fluid pressure acting on the vane surfaces **70** and **74** offset each other. This follows from the fact that the inner edge surface **74** of each vane is continuously connected with the outer edge surface **70** of the vane through the end grooves **76** and the bores **78** formed in each vane as described.

However, the effective area of the outer edge surface **70** of each vane, which is continuously connected with the inner edge surface **74**, is not necessarily precisely equal to the effective area of the inner surface **74** because of the formation on the outer edge of the vane of the two narrow sealing edges **66, 68**. Yet, for the purpose of understanding the present invention, the effective area of the outer edge surface **70** of each vane may be regarded as being the same as that of the inner edge surface **74** of the vane, so that the forces of equal fluid pressure on the two opposed surfaces **70, 74** are substantially balanced.

Also, it may be observed, with reference to FIGS. 5 and 6, that the outer end **153** of each high pressure vane actuating plunger **98** is pointed somewhat in the form of a truncated cone to localize the engagement of the plunger with the inner edge of the adjacent vane. The outer end **153** of each plunger **98** is exposed to the same fluid pressure which acts on the adjacent vane surface **74**.

The inner and outer forces of equal fluid pressure applied to the outer and inner edge surfaces **70, 74** of each vane may be regarded as substantially offsetting each other. Yet provision is specifically made for creating and using pressure imbalances or pressure differentials on the inner and outer edge surfaces **74, 70** of each vane to materially aid in maintaining optimum engagement of the vane with the cam surface **28** as the vane moves through and beyond each fluid discharge zone **154**.

In this connection, it is necessary to bear in mind that the maintenance of optimum engagement of the orbiting vanes with the cam surface **28** not only involves the matter of continuously applying to each vane sufficient outward force to hold the vane in engagement with the cam surface, but also the avoidance of excessive pressure engagement of each vane with the cam surface.

As each vane passes through a fluid discharge zone **154** (see FIG. 2) the vane must move inwardly from its fully extended position to its retracted position. This requires that the vane passing through a fluid discharge zone be accelerated inwardly by an inward force in contrast to the outward force which must be applied to each vane to accelerate the vane outwardly as it moves through an intake zone **150**, as described. As each vane **62** moves into a fluid discharge zone **154** the fluid pressure on the outer edge surface **70** of the vane reaches the full output pressure of the pump with the result that the coacting plunger **98** is no longer effective to urge the vane outwardly.

As each vane moves into a fluid discharge zone **154**, the cam surface **28** acts on the vane to accelerate the vane radially inward. When the rotor is turning fast, vanes moving through afluid discharge zone gain a correspondingly high radially inward velocity.

The radially inward velocity gained by each vane moving through a fluid discharge zone **154** must be fully dissipated by the time the vane passes from the discharge zone into the adjacent sealing zone **156**. Otherwise, the vane will move inwardly too far with the result that some or all of the vanes will separate from the cam surface **28** and "ski jump" over an arc of the cam surface upon entering the sealing zone **156** adjacent a fluid discharge zone **154**. The result of any such separation from the cam surface can be a cause of accelerated wear on the cam surface and vanes and a material shortening of the service life of the unit, and it can permit fluid to pass intermittently from the high pressure fluid zone **154** across the sealing zone **156** to the low pressure zone **150** whenever the "ski jumping" vane is separated from the cam surface **28** within a sealing zone **156**, thereby materially reducing the efficiency of the unit.

To avoid jumping or skipping of a portion of the cam surface by vanes passing from a fluid discharge zone **154** to a sealing zone **156** it is necessary that the inwardly moving vanes be opposed by an outward vane decelerating force having sufficient strength to overcome the inward momentum of each vane and hold it in contact with the cam surface.

The outward forces on each vane passing from a fluid discharge zone **154** include the centrifugal force produced by the mass of the vane, the plunger **98** and the springs **134, 136** as well as the forces of the springs **134, 136**.

Each vane plunger **98**, which is rendered hydraulically ineffective to urge the coacting vane outwardly upon entry of the coacting vane into a fluid discharge zone **154**, again becomes effective to urge the coacting vane outwardly after the vane has passed beyond the discharge zone into into an adjacent sealing zone **156** and the fluid pressure on the outer vane edge surface **70** has dropped below the full output pressure of the pump. However, since the capability of each vane plunger **98** of exerting hydraulically a net outward force on its coacting vane increases as the fluid pressure on the outer vane edge surface **70** decreases, the powerful hydraulic output force which each vane provides for extending the coacting vane and maintaining it in optimum pressure contact with the cam surface as the vane moves through a fluid intake zone **150** and the adjacent transfer zone **152**, as described, is not fully available for supplying radial force needed in maintaining assured contact of the vane with the cam surface as the vane passes from a fluid discharge zone **154** into an adjacent sealing zone **156**.

The cumulative value of the centrifugal and spring forces acting on each vane as it passes from a fluid discharge zone **154** may not be sufficient to overcome the inward momentum of the vane and keep it in contact with the cam surface, particularly at high rotor speeds. In this connection, it should be borne in mind that the strength of the springs **134, 136** coacting with each vane is limited by space restrictions with corresponding limitations on the strength of the springs.

The high pressure plunger **98** associated with each vane affords the inherent advantages of providing a powerful outward vane extending force where it is most needed in each fluid intake zone. Also, the outward force of each vane plunger **98** effectively disappears at the leading end of each discharge zone so that it does not oppose the necessary inward acceleration of each vane. Yet, despite these advantages, the high pressure plungers **98** are of little or no help in decelerating the inward velocity

of the vanes as the vanes pass from the fluid discharge zones 154.

Deceleration of the inward velocity of the vanes 62 is very effectively aided by a fluid pressure differential dynamically produced and applied to each vane only as it is needed for decelerating the vane radially.

As shown in FIG. 1, the housing section 38 is shaped to define two elongated inner fluid outlet ports 159 which open through the rotor opposing surface 36 in radially inward relation to the respective fluid outlet ports 58, FIG. 2. Each inner discharge port 159 is positioned radially and circumferentially with reference to the axis of the rotor and the corresponding fluid discharge zone 154, so that the inner portion of each vane slot 64 is in communication with theinner port 159 when the corresponding vane enters the ramp portion of the cam surface 28 which is within the fluid discharge zone 154.

As shown, the inner extremities of the individual vane slots 64 are axially bored with reference to the rotor to have a segmental cylindrical form 160, FIG. 2, and when each vane 62 is passing through an early portion of each discharge zone 154 the inner end of the corresponding vane slot is in communication with the corresponding inner discharge port 159.

The face 36 of the housing section 38 confronting the rotor 22 is as shown, shaped to define a groove 162 confronting the rotor and extending from each inner fluid outlet port 159 to the leading end of the adjacent outer outlet port 58, FIGS. 2 and13.

While the dynamic fluid action that takes place in each fluid discharge zone 154 can be most simply and accurately visualized with refernce to the adjacent fluid outlet ports 58 and 159 and outlet grooves 162 in the housing section 38, it should be pointed out with reference to FIGS. 1 and 4 that counterparts of the outlet ports and grooves in the housing section 38 are formed in the cheek plate 42. For each fluid discharge zone 154, the cheek plate 42 defines an inner port 165, an outer port 167, and a groove 163 opening through the plate surface 40 in a pattern FIG. 4, forming substantially a mirror image of the opposing outlet ports 159, 58 and groove 162 in the housing section 38. One of the inner cheek plate ports 165 is connected to the adjacent outer port 167 by the previously mentioned passage 124, FIG. 1, and the other inner port 165 is connected to the adjacent outer port 167 by a similar passage 169 in the cheek plate. The outer cheek plate ports 167 communicate through adjacent portions of the pumping spaces 32 with the opposing outlet ports 58.

If desired, the grooves 162 and 163 used in the preferred construction illustrated can be omitted.

Having reference to FIG. 13, each vane 62 upon moving into a fluid discharge zone 154 is effectively relieved of the outward hydraulic force of the coacting high pressure plunger 98. This removal of the radially outward hydraulic force on the vane at that point at which it begins to traverse the cam ramp within the discharge section is highly advantageous since it is at this point that the inward acceleration of the vane is the greatest and therefore it is at this point that the greatest frictional forces between the cam surface 28 and the outer end of the vane exist. From the foregoing it will be seen that the tendency for the vane to gouge into the cam surface, at least on the leading portion of the ramp within the discharge section 154 will be minimized.

During an early phase of the movement of a vane through a discharge zone 154, FIG. 13, the spring forces and the reversed effective force of vane acceleration which urge the vane against the cam surface 28 are supplemented by a differential fluid pressure force on the vane produced dynamically as an incident to the forcing of fluid from the coacting vane slot inwardly of the vane. Inward movement of the valve forces fluid from the inner portion of the coacting vane slot out through the ports 159, the vane bores 78 and out through the end grooves 76 in the vane. The fluid resistance to the outflow of liquid through the ports 159, the bores 78 and grooves 76 is relatively low, with the result that inward resistance to the movement of the vane by hydraulic forces is minimized.

As movement of the vane progresses through a fluid discharge zone 154, the end grooves 76 in the vane move into registry with the outer ends of the grooves 162, 163 in the housing section 38 and cheek plate 42, respectively. The grooves 162, 163 are disposed in oblique positions with reference to the plane of an adjacent vane so that registration or alinement of the grooves 162, 163 with the end grooves 76 in a passing vane begins at the periphery of the rotor 22 and progresses radially inward toward the inner edge of the vane as movement of the vane continues in the rotary direction described. The effect of this is to progressively shorten the path of fluid which escapes from the inner portion of each passing vane slot out through the vane end grooves 76 in the coacting vane into the fluid discharge grooves 162, 163. Consequently, the resistance to the outflow of fluid from beneath the vane is even further reduced by the presence of the grooves 162 and 163, although, as previously stated, these grooves may be omitted if desired, and particularly when the ports 159, 165 are of sufficient size to accommodate the flow of fluid from beneath the vane in a substantially unrestricted manner.

Continued rotary movement of each vane within each fluid discharge zone 154 brings the inner portion of the corresponding vane slot 64 progressively into full alinement with the inner fluid outlet ports 159, 165 for the discharge zone. The effect of this is to reduce and virtually eliminate the dynamically produced differential pressure on the vane surfaces 74 and 70 which urges the vane outwardly. The result is to minimize the fluid resistance to inward vane movement where such resistance is undesirable.

After the van passes from the position shown in FIG. 14, the vane must be radially decelerated to hold it in engagement with the cam surface 28. As illustrated in FIG. 15, continued rotary movement of a vane 62 moves the inner portion of the coacting vane slot 64 progressively out of registration with the adjacent inner ports 159, 165 so that the fluid which must be subsequently discharged from the inner portion of the vane slot must pass out through the relatively restricted vane bores 78 and vane end groves 76. The result is to recreate dynamically a pressure differential on the inner and outer vane surface 74, 70 which acts outwardly to aid in decelerating inward movement of the vane as desired.

In this connection, it should be appreciated that because of the rather large area of the inner edge surface 74 of each vane, the volume of fluid displaced from the coacting vane slot as the vane moves inwardly is correspondingly large, particularly in relation to the volume of fluid displaced by the coacting vane plunger 98 from its cylinder 96. The relatively large volume of the fluid which must pass from each vane slot 64 within each fluid discharge zone 154 makes it easier to control throtting or choking of the outflow of fluid from each vane slot in synchronized relation to rotary movement of the coacting vane to obtain the desired radial deceleration of the vane. The rather substantial volume of fluid involved tends to relax the dimensional tolerances on the position and size of the grooves 162, 163 and inner ports 159, 165 which coact with the vanes to produce the desired dynamic vane decelerating forces.

As each vane progresses from a fluid discharge zone 154 through the adjacent sealing zone 156, it is effectively urged into sealing engagemednt with the cam surface 28 by the coacting springs 134, 136. Also, there is a progressive escape of high pressure fluid trapped in the coating vane slot with the result that the pressure on the outer edge surface 70 of the vane progressively decays. The result is a progressive reactivation of the effective-

ness of the high pressure vane plunger **98** in applying a net outward force to the vane, so that when the vane reaches the next fluid intake zone **150** both the springs **134, 136** and the high pressure plunger are fully effective to urge the vane outwardly, as previously described.

It is particularly noteworthy that even though the springs **134, 136** for each vane do not necessarily have sufficient strength of themselves to maintain the vane in continuous contact with the cam surface **28**, the springs serve a highly advantageous function in maintaining the coacting vane in engagement with the cam surface when the high pressure vane plunger **98** is not fully effective. In particular, the springs serve to great advantage in maintaining contact of the coacting vane with the cam surface as the vane moves from each fluid outlet zone **154** into and through the adjacent sealing zone **156**.

Also, the vane springs **134, 136** serve to advantage when the unit is used as a fluid motor, in which instance the springs assure contact of the vanes with the cam surface **28** for starting the unit.

As each vane **62** moves outwardly within each fluid intake zone **150**, fluid must flow into the inner portion of the coacting vane slot **64** to fill the space within the slot inwardly of the vane. The matter of maintaining the space within each vane slot inwardly of the vane filled with fluid as the vane moves outwardly within each fluid intake zone **150** is complicated by the relatively low pressure at which the incoming fluid is supplied to the intake zone and the extreme brevity of the time period within which the vane remains in the intake zone. In this connection, it should be appreciated that the high speed with which a vane moves outwardly within each fluid intake zone **150** tends to create a suction or partial vacuum at the inner edge surface **74** of the vane. While this reduction of pressure at the inner edge surface **74** of the vane can aid in sucking fluid into the corresponding vane slot, the diminution in pressure on the inner vane surface **74** tends to create a differential pressure on the vane surfaces **70** and **74** which acts inwardly to oppose outward movement of the vane. This differential pressure can arise dynamically, even though the inner and outer vane edge surfaces **74** and **70** are connected, as described.

Incoming fluid for filling the vane slots **64** inwardly of the vanes **62** is supplied to opposite end faces of the rotor within each fluid intake zone **150** by two inner fluid supply ports **168, 170** formed in the housing section **38** and check plate **42** to open through the rotor opposing surfaces **36** and **40** in circumferential alinement with but inwardly spaced relation to the outer fluid supply ports **52, 54** in each fluid intake zone **150**, FIGS. 2, 3 and 4. Even though the inner fluid supply port **168, 170** supply fluid to the inner portion of each passing vane groove **64**, the movement of fluid into each passing vane groove to minimize dynamic creation of differential pressure opposing outward vane movement is nevertheless inhibited by the relatively low fluid inlet pressure and the very limited time available for fluid flow.

In applicants' pump, the in flow of fluid into the vane slots is speeded up to great advantage by the shape of the space within each slot **64** which is filled with fluid upon extension of the coacting vane. The shaping of this space is such that the inflow of fluid into the space is accelerated to advantage by centrifugal force acting on the inflowing fluid. This feature of applicants' pump is provided to a certain degree in the pump just described, but is provided to a greater degree in the modified pump illustrated in FIGS. 9 and 10 in which component elements corresponding to component elements of the pump previously described are identified by the same reference numbers with the addition of the suffix *a*.

In the modified pump illustrated in FIGS. 9 and 10, the rotor reinforcing and plunger cylinder defining structure which extends radially outward beyond the inner extremities of the respective vane slots **64***a* is formed as an integral part of the rotor **22***a*. The central notch **82***a* formed in the inner portion of each vane **62***a* is shaped to diverge in a radially inward direction, as illustrated in FIG. 9, so that the opposite side edges **180** intersect opposite axial ends of the vanes at the inner extremities of the vanes. The bottom of each vane slot **64***a* is shaped to have, as viewed in a transverse axial section of the rotor, FIG. 9, a truncated triangular form projecting out into the coacting vane notch and corresponding generally in shape to the notch, as shown. Thus, the space **182** between the bottom of each vane slot and the inner edge of the adjacent vane slopes radially outward from the two ends of the rotor.

Consequently, when the inner ends of the vane slots **64***a* move into alinement with a pair of inner fluid supply ports, the incipient flow of fluid from the inner ports into the vane slot space **182** is immediately subjected to centrifugal force which accelerates the flow of fluid toward the center of the vane space **182** which is located radially outward of the opposite ends of the space **182**. Hence, this shaping of the vanes and slots so that the central portion of each slot space **182** is located radially outward of the axial end portions of the space **182** produces a highly advantageous centrifugal pumping action that greatly accelerates the inflow of fluid into each slot, as desired.

It will be appreciated, with reference to FIG. 9, that the integral portion of the rotor **22***a* which extends out into each vane notch **82***a* as illustrated and described constitutes an integral protuberance **184** of the rotor which provides the desired mutual reinforcement of adjacent sectors **151***a* of the rotor which define the adjacent rotor slot. Each integral rotor protuberance **184** is bored to define a cylinder **96***a* for the corresponding high pressure vane plunger **98***a*.

In another modified form of the invention illustrated in FIGS. 11 and 12, component elements similar to components of the first described embodiment of the invention are identified with the reference numbers with the addition of the suffix *b*. This form of the invention differs from that illustrated in FIGS. 1 to 8 in that the width of each vane notch **82***b* in an axial direction with respect to the rotor is substantially enlarged and the corresponding width of each plug **84***b* is similarly enlarged. The enlarged plugs **84***b* provide for a stronger mutual reinforcement of the rotor sectors **151***b* intervening between and defining the vane slots **64***b*.

It will be appreciated that even though the notch **82***b* in each vane **62***b* does not progressively widen in a radially inward direction, the central portion of the notch is located radially outward of the inner extremities of the vane, which are disposed at opposite axial ends of the vane. As a consequence, incoming fluid flowing into the vane notch **82***b* is subjected to centrifugal force which aids materially in filling the coacting vane slot **64***b* inwardly of the vane moves outwardly, as described. In a similar manner, the inflow of fluid into the notch **82** in each vane **62** in the pump first described is accelerated by centrifugal force.

It will be appreciated that the invention is not necessarily limited to use of the particular constructions illustrated, but includes use of variants and alternatives within the spirit and scope of the invention as defined by the claims.

The invention is claimed as follows:

1. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor, said cam surface being shaped and positioned in relation to the periphery of said rotor to define therewith a working space for fluid, said housing defining flow passages communicating with said space at spaced positions therealong, said rotor defining an annular series of vane slots therein opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said

respective slots to extend from the periphery of the rotor into continuous engagement with said cam surface, each vane being slidable in its slot betwen a fully extended position and a fully retracted position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a notch extending between opposite sides of the vane and extending outwardly in the vane for an extended distance from the inner extremity of the vane, plugs disposed within said respective vane slots to extend into said notches of the coacting vanes for substantial distances outwardly of the positions occupied by the inner extremities of the respective vanes when the respective vanes are moved into their retracted positions in the slots by said cam surface, said plugs each being shaped and dimensioned to firmly engage simultaneously the two opposing side surfaces of the associated slot to effect by means of the plugs a mutual reinforcement of said intervening rotor sectors, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, each of said plugs defining a cylinder therein generally parallel to the plane of the adjacent vane and opening outwardly toward the inner edge of the adjacent vane at the bottom of said notch in the vane, a plunger slidably mounted in said cylinder of each plug to react outwardly on the adjacent vane, means for supplying fluid under pressure from the high pressure end of said working space to said plug cylinders at the inner ends of said plungers to apply fluid pressure to said plungers for urging said vanes outwardly, each of said vanes defining two surfaces thereupon which are substantially continuously exposed to the pressure of fluid in the interspace adjacent the vane between the periphery of the rotor and said cam surface, one of said surfaces on each vane being oriented so that the force of fluid pressure on the vane urges the vane away from said cam surface and the other of said surfaces on each vane being oriented so that the force of fluid pressure thereon urges the vane toward said cam surface, spring means disposed within each of said vane slots and being stressed continuously to urge the adjacent vane outwardly in the vane slot, said spring means in each slot having a movable power applying portion which acts on the adjacent vane and moves in and out with the vane as the vane moves in and out in its slot, and said spring means in each slot having a support portion which reacts on the rotor to transmit thereto the reaction of the adjacent vane on the spring means and which is stationary with respect to the rotor so that the spring means is flexed and stores energy upon inward movement of the vane and subsequently releases energy by relaxation to extend the vane.

2. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor, said cam surface being shaped and positioned in relation to the periphery of said rotor to define therebetween a working space for fluid, said housing defining flow passages communicating with said working space at spaced positions therealong, an annular series of circumferentially spaced vane units carried by said rotor, each vane unit including a vane mounted in a coacting slot defined by said rotor, each vane being slidable within its coacting slot to project therefrom into sliding engagement with said cam surface, each vane unit defining first and second vane biasing surfaces associated with the vane of the unit and being continuously exposed to the pressure of fluid in the interspace adjacent the vane between said rotor and said cam surface, said first biasing surface for each vane being oriented so that the force thereon of fluid pressure urges the vane inwardly, said second biasing surface of each unit being oriented so that the force of fluid pressure thereon urges the vane outwardly, each vane unit defining a third biasing surface associated with the coacting vane and oriented so that the force of fluid pressure on said third surface urges the coacting vane outwardly, each vane unit including means associated therewith to isolate said third biasing surface thereof from direct communication with said second biasing surface of the unit, means associated with each unit for supplying to said third biasing surface thereof fluid under high pressure from a high pressure portion of said working space for fluid, each vane unit including spring means stressed to urge the vane of the vane unit outwardly in its coacting vane slot, said spring means of each vane unit having a movable power applying portion which acts on the vane of the vane unit and moves in and out with the vane as the vane moves in and out in its slot, and said spring means of each vane unit having a support portion which reacts on the rotor to transmit thereto the reaction of the coacting vane on the spring means and which is substantially stationary with respect to the rotor so that the spring means is flexed and stores energy upon inward movement of the vane and subsequently releases energy by relaxation to extend the vane.

3. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor, said cam surface being shaped and positioned in relation to the periphery of said rotor to define therewith a space for fluid, said housing defining flow passages communicating with said space at spaced positions therealong, said rotor defining therein an annular series of outwardly open vane slots separated by intervening sectors of the rotor, a plurality of vanes slidably in said respective slots to extend from the periphery of the rotor into continuous engagement with said cam surface, each vane being slidable in its slot between a retracted position and an extended position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a notch extending between opposite sides of the vane and extending outwardly in the vane for an extensive distance from the inner extremity of the vane, a rotor reinforcing plug disposed within each of said vane slots and extending into said notch of the coacting vane for a substantial distance outwardly of the position occupied by the inner extremity of the vane when the vane is moved into its retracted position in its slot by said cam surface, each of said plugs being shaped and dimensioned to firmly engage simultaneously the two opposing side surfaces of the associated slot to effect by means of the plugs a mutual reinforcement of said intervening rotor sectors, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, each of said plugs defining a cylinder therein opening outwardly toward the inner edge of the vane at the bottom of said notch in the vane, a plunger slidably mounted in said cylinder of each plug to react outwardly on the adjacent vane, means for supplying fluid under pressure from said fluid space to said plug cylinders at

the inner ends of said plungers to apply fluid pressure to said plungers for urging said vanes outwardly, and each vane and the structure coacting therewith including means providing communication between the inner edge of the vane and the interspace adjacent the vane between the periphery of the rotor and said cam surface so that the force of fluid pressure on the outer end of each vane tending to urge the vane inwardly is opposed by the force of fluid pressure on the inner edge of the vane tending to urge the vane outwardly.

4. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor and coacting therewith to define a fluid working space having fluid inlet and outlet zones, said housing defining passageways communicating with said inlet and outlet zones of said working space, said rotor defining therein an annular series of vane slots opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said respective vane slots to extend from the periphery of the rotor into continuous engagement with said cam surface, each vane being slidable in its slot between a retracted position and an extended position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane being shaped to have an inner end portion which extends outwardly a substantial distance from the inner extremity of the vane and has a transverse sectional area which is materially less than the corresponding transverse sectional area of a portion of the vane located outwardly of said inner end portion, each of said vane slots including an inner portion adapted to receive said inner portion of the coacting vane and being reduced in transverse sectional area in relation to the transverse sectional area of an outer portion of the vane slot by an element which is rigid with the rotor and positioned to overlap said inner end portion of the coacting vane when the latter is in a retracted position, the portion of each intervening rotor sector that extends radially inward from the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, said element in each vane slot defining a cylinder opening outwardly toward the opposing inner edge of the coacting vane, a plunger slidably mounted in each cylinder to act outwardly on the adjacent vane, means including an automatic pressure switching valve connecting inlet and outlet zones of said working space with said cylinders to supply fluid automatically from the zone under the higher fluid pressure to each cylinder to act on the plunger therein to urge the plunger and the coacting vane outwardly, each of said vanes and the structure associated therewith including means for supplying fluid to the inner edge of the vanes to oppose the inward force of fluid pressure on the outer edge of the vane, spring means disposed within each of said vane slots and being stressed to urge the adjacent vane outwardly in the vane slot, said spring means in each slot having a movable power applying portion which acts on the adjacent vane and moves in and out with the vane as the vane moves in and out in its slot, and said spring means in each slot having a support portion which reacts on the rotor to transmit thereto the reaction of the adjacent vane on the spring means and which is stationary with respect to the rotor so that the spring means is flexed and stores energy upon inward movement of the vane and subsequently releases energy by relaxation to extend the vane.

5. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor, said cam surface being shaped and positioned in relation to the periphery of said rotor to define therewith a space for fluid, said housing defining flow passages communicating with said space at spaced positions therealong, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said respective slots to extend from the periphery of the rotor into engagement with said cam surface, each vane being slidable in its slot between a retracted position and an extended position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a notch extending between opposite sides of the vane and extending outwardly in the vane from the inner extremity of the vane, a plurality of rigid elements corresponding to said respective vanes, said rigid elements extending into said notches of the respective vanes for substantial distances outwardly of the positions occupied by the inner extremities of the respective vanes when the vanes are moved into their retracted positions by said cam surface, each of said rigid elements being firmly associated with the two rotor sectors embracing the adjacent vane whereby the rigid elements effect a mutual reinforcement of said intervening rotor sectors, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, each of said rigid elements defining a cylinder therein generally parallel to the plane of the adjacent vane and opening outwardly toward the inner edge of the adjacent vane, a plunger slidably mounted in said cylinder of each rigid element and coacting with the adjacent vane to react outwardly thereon, means for supplying fluid under pressure from said fluid space to said cylinders at the inner ends of said plungers to apply fluid pressure to said plungers for urging said vanes outwardly, each of said vanes and the structure coacting therewith including means for applying fluid pressure to the inner edge of the vane to urge the vane outwardly, spring means coacting with each of said vanes and being stressed to urge the vane outwardly in its slot, said spring means for each vane having a movable power applying portion which acts on the vane and moves in and out with the vane as the vane moves in and out in its slot, and said spring means for each vane having a support portion which reacts on the rotor to transmit thereto the reaction of the coacting vane on the spring means and which is stationary with respect to the rotor so that the spring means is flexed and stores energy upon inward movement of the vane and subsequently releases energy by relaxation to extend the vane.

6. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor and defining with the periphery thereof a working space for fluid, said rotor defining therein an annular series of vane slots opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said respective vane slots to extend from the periphery of the rotor into continuous engagement with said cam surface, each vane being slidable in its slot between a retracted position and an extended position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane, each vane being shaped to have an

inner end portion which extends outwardly a substantial distance from the inner extremity of the vane and has a transverse sectional area which is materially less than the corresponding transverse sectional area of a portion of the vane located outwardly of said inner end portion, each of said vane slots including an inner portion adapted to receive said inner portion of the coacting vane and being reduced in transverse sectional area in relation to the transverse sectional area of an outer portion of the vane slot by an element which is rigid with the rotor and positioned to overlap said inner end segment of the coacting vane when the latter is in a retracted position, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, said element in each vane slot defining a cylinder opening outwardly toward the opposing inner edge of the coacting vane, a plunger slidably mounted in each cylinder to act outwardly on the adjacent vane, said rotor having means thereon providing communication between a high pressure zone of said working space and said cylinders to supply high pressure fluid to each cylinder to act on the inner end of the plunger therein to urge the plunger and the coacting vane outwardly, and each of said vanes and the structure associated therewith including means providing communication between the inner edge of the vane and the interspace adjacent the vane between the rotor and the outer end of the vane.

7. A rotary vane fluid power unit comprising, in combination, a rotor; a housing encasing said rotor and including means defining a cam surface encircling said rotor and coacting therewith to define, for fluid, working space having fluid inlet and outlet zones; said housing including means defining passageways communicating with said inlet and outlet zones of said working space, said rotor defining an annular series of vane slots therein opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said respective vane slots to extend from periphery of the rotor into engagement with said cam surface, each vane being slidable in its slot between a retracted position and an extended position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a notch extending outwardly in the vane from the inner extremity thereof, a plurality of plugs fitted into said respective vane slots to extend outwardly into said notches in the respective vanes, said plugs each engaging firmly the two rotor sectors on opposite sides of the corresponding slot to effect mutual reinforcement of said intervening rotor sectors, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, spring means disposed within each of said vane slots and being stressed to urge the adjacent vane outwardly in the vane slot, said spring means in each slot having a movable power applying portion which acts on the adjacent vane and moves in and out with the vane as the vane moves in an out in its slot, said spring means in each slot having a support portion which reacts on the rotor to transmit thereto the reaction of the adjacent vane on the spring means and which is stationary with respect to the rotor so that the spring means is flexed and stores energy upon inward movement of the vane and subsequently releases energy by relaxation to extend the vane, each of said plugs defining a cylinder therein, a plunger disposed in each of said plug cylinders and coacting with the adjacent vane to apply an outward force thereto, means including an automatic pressure switching valve connecting inlet and outlet zones of said working space with said cylinders to supply fluid automatically from the zone under the higher fluid pressure to each cylinder to act on the plunger therein to urge the plunger and the coacting vane outwardly, and each of said vanes and the structure associated therewith including means for supplying fluid to the inner edge of the vane to oppose the inward force of fluid pressure on the outer edge of the vane.

8. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor and being shaped and positioned in relation to the periphery of the rotor to define therebetween a working space for fluid, said rotor defining therein an annular series of vane slots opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said respective vane slots to extend from the periphery of the rotor into continuous engagement with said cam surface, each vane being shaped to have an inner end segment which has a transverse sectional area which is materially less than the corresponding transverse sectional area of a portion of the vane located outwardly of the inner end segment thereof, each of said vane slots including an inner segment adapted to receive said inner segment of the coacting vane and being reduced in transverse sectional area in relation to the transverse sectional area of an outer portion of the vane slot by an element which is rigid with the rotor and positioned to overlap said inner end segment of the coacting vane when the latter is in a retracted position, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, said element in each vane slot defining a cylinder opening outwardly toward the opposing inner edge of the coacting vane, a plunger slidably mounted in each cylinder to act outwardly on the adjacent vane, said rotor having means thereon providing communication between a high pressure zone of said working space and said cylinders to supply high pressure to act on the inner end of the plunger therein to urge the plunger and the coacting vane outwardly, each of said vanes and the structure associated therewith including means providing communication between the inner edge of the vane and the interspace adjacent the vane between the rotor and the outer end of the vane, spring means coacting with each vane and being stressed continuously to apply to the vane an outward force which is cumulative with the outward forces on the vane of fluid pressure acting on the inner edge of the vane and fluid pressure acting on the coacting plunger said spring means for each vane having a movable power applying portion which acts on the vance and moves in and out with the vane as the vane moves in and out in its slot, and said spring means for each vane having a support portion which reacts on the rotor to transmit thereto the reaction of the vane on the spring means and which is stationary with respect to the rotor so that the spring means is flexed and stores energy upon inward move-

ment of the vane and subsequently releases energy by relaxation to extend the vane.

9. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor, said cam surface being shaped and positioned in relation to the periphery of said rotor to define therewith a working space for fluid, said housing defining flow passages communicating with said space at spaced positions therealong, said rotor defining an annular series of vane slots therein opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said respective slots to extend from the periphery of the rotor into continuous engagement with said cam surface, each vane being slidable in its slot between a retracted position and a fully extended position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a notch extending between opposite sides of the vane and extending outwardly in the vane for an extended distance from the inner extremity of the vane, and plugs disposed within said respective vane slots to extend into said notches of the coacting vanes for substantial distances outwardly of the inner extremities of the respective vanes when the respective vanes are moved into retracted positions in the coacting slots by said cam surface, said plugs each being shaped and dimensioned to firmly engage simultaneously the two opposing side surfaces of the associated slot to effect by means of the plugs a mutual reinforcement of said intervening rotor sectors, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended.

10. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor and coacting therewith to define a fluid working space having fluid inlet and outlet zones, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, a plurality of vanes mounted in said respective vane slots to extend outwardly therefrom into engagement with said cam surface, each vane being shaped to have a radially inner portion which extends outwardly a substantial distance from the inner extremity of the vane and has an area in transverse section generally parallel to the axis of the rotor that is materially less than the corresponding transverse sectional area of a portion of the vane located outwardly of said inner portion, each of said vane slots including an inner portion adapted to receive said inner portion of the coacting vane and having an area in a transverse section generally parallel to the rotor axis which is reduced in relation to the corresponding transverse sectional area of an outer portion of the vane slot by an element which is rigid with the rotor and positioned to overlap said inner portion of the coacting vane when the latter is in a retracted position, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, said element corresponding to each vane slot defining a cylinder opening outwardly toward the opposing inner edge of the coacting vane, a plunger slidably mounted in each cylinder to act outwardly on the adjacent vane, means including an automatic pressure switching valve connecting said inlet and said outlet zones of said working space with said cylinders to supply fluid automatically from the zone under the higher fluid pressure to each cylinder to act on the plunger therein to urge the plunger and the coacting vane outwardly, and each vane having associated therewith means providing continuous communication for fluid between the inner and outer edges of the vane.

11. A rotary vane pump comprising in combination, a rotor, housing means encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having an inlet zone and an outlet zone, said housing means including fluid supply means for supplying fluid to said working space at said inlet zone thereof, said housing means including means for discharging fluid from said outlet zone of the working space, said rotor defining an annular series of vane slots, a plurality of vanes slidably mounted in said respective vane slots to extend outwardly therefrom into engagement with said cam surface for movement along said cam surface through said working space upon rotation of the rotor, said fluid supply means including means defining fluid supply passages confronting opposite ends of said rotor and registering radially with adjacent inner portions of passing vane slots to supply fluid to the inner portion of each of said vane slots at both ends of the rotor as an incident to movement of the associated vane through said intake zone of said working space, each vane having an inner edge shaped to have radially inward extremities located adjacent opposite ends of said rotor and to have an outwardly offset medial portion located radially outward of said inner extremities of the vane, and the inner portion of each vane slot being shaped and dimensioned in relation to the inner edge of the adjacent vane to provide upon outward displacement of the vane from its innermost position free flowing so that fluid entering the inner portion of each vane slot from said passages is centrifugally urged toward said medial portion of the inner edge of the adjacent vane.

12. A rotary vane pump comprising in combination, a rotor, housing means encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having an inlet zone and an outlet zone, said rotor defining an annular series of vane slots, a plurality of vanes slidably mounted in said respective vane slots to extend outwardly therefrom into engagement with said cam surface for movement along said cam surface through said working space upon rotation of the rotor, said housing means including fluid supply means communicating with said fluid working space at said inlet zone thereof and defining fluid supply passage space confronting opposite ends of said rotor at positions that are alined circumferentially with inlet zone and that register radially with the inner portions of the vane slots opening through the two ends of the rotor to supply fluid to the inner portion of each of said vane slots at both ends of the rotor as an incident to movement of the associated vane through said intake zone of said working space, and each vane having two inner extremeties located adjacent opposite ends of the rotor and having an inner edge that is shaped between said inner extremities of the vane to define a medial notch having opposite sides diverging radially inward so that fluid entering the inner portion of the coacting slot from said passage space at opposite ends of the rotor is centrifugally urged to flow radially outward and axially inward along the inwardly diverging sides of said vane notch toward the center of said vane notch to fill

the slot inwardly of the vane as the vane moves outwardly in said inlet zone.

13. A rotary vane fluid pump comprising, in combination, a rotor, means defining a cam surface encircling said rotor and defining therewith a pumping space having fluid inlet and outlet zones, fluid supply means for supplying fluid to said pumping space at said inlet zone thereof, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed in said respective slots for engagement with said cam surface, each of said vanes having an inner portion thereof defining a notch opening radially inward and having side edges diverging in a radially inward direction to inner extremities of the vane located adjacent opposite ends of the rotor, means on said rotor defining a plurality of protuberances corresponding to said respective slots, each protuberance being positioned with reference to its corresponding slot to extend outwardly into said notch in the coacting vane when the vane is in a retracted position, and said fluid supply means including means defining fluid supply passage spaces confronting opposite ends of said rotor in positions which register with the radially inward portions of the vane slots in the rotor as the slots move the coacting vanes through said inlet zone of said pumping space.

14. A rotary vane fluid pump comprising, in combination, a rotor, means defining a cam surface encircling said rotor and defining therewith a pumping space having fluid inlet and outlet zones, fluid supply means for supplying fluid to said pumping space at said inlet zone thereof, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed in said respective slots for engagement with said cam surface, each of said vanes having an inner portion thereof defining a notch opening radially inward and having side edges diverging in a radially inward direction to inner extremities of the vane located adjacent opposite ends of the rotor, a plurality of rotor reinforcing elements corresponding to said respective slots, each reinforcing element being positioned with reference to the coacting slot to extend into said notch in the coacting vane when the vane is in a retracted position, each reinforcing element extending between and firmly coacting with portions of the rotor on opposite sides of the corresponding slot to effect mutual reinforcement of portions of the rotor defining the slot, each reinforcing element defining a plunger cylinder therein, a plunger slidably disposed in each cylinder and engaging the coacting vane, means for supplying fluid under pressure to each cylinder to urge the coacting plunger and vane outwardly, said fluid supply means including means defining fluid supply passage spaces confronting opposite ends of said rotor in positions which register with the radially inward portions of the vane slots in the rotor as the slots move the coacting vanes through said inlet zone of said pumping space, and spring means coacting with each vane to urge the vane outwardly.

15. A rotary vane fluid power unit comprising, in combination, a rotor, housing means encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having fluid inlet and outlet zones, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed within said respective vane slots for engagement with said cam surface, said housing means including means for supplying fluid to the intake zone of said fluid working space, said housing means including fluid outlet means for releasing fluid from said outlet zone of said fluid working space, said fluid outlet means including means defining outlet passage space confronting one end of said rotor, and said outlet passage space having a position such that upon turning of said rotor to discharge fluid from said outlet zone of said working space each vane slot carrying a vane through the outlet zone of the working space is brought into an alinement with the passage space which alinement reaches a maximum value when the coacting vane is passing through a medial portion of said fluid outlet zone and which is greatly reduced before the coacting vane passes beyond said fluid outlet zone.

16. A rotary vane fluid power unit comprising, in combination, a rotor, housing means encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having fluid inlet and outlet zones, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed within said respective vane slots for engagement with said cam surface, said housing means including means for supplying fluid to the intake zone of said pumping space, said housing means including fluid outlet means for releasing fluid from said outlet zone of said fluid working space, said fluid outlet means including means defining an inner fluid outlet port confronting one end of said rotor inwardly of the periphery of the rotor and being positioned for registration with the radially inward portion of each vane slot as the vane slot carries the coacting vane through a medial portion of said outlet zone of said fluid working space, each of said vanes defining in the axial end thereof adjacent said one end of said rotor a groove extending from the inner to the outer edge of the vane; said housing means including means defining a fluid outlet passage confronting said one end of the rotor and extending generally from said inner outlet port to the periphery of the rotor and having a positional orientation such that, upon turning of said rotor in a rotary direction which discharges fluid from said working space outlet zone, said end groove in each vane passing through said outlet zone of said fluid working space establishes a communicating alinement with said outlet passage which begins at the periphery of the rotor and progresses inwardly to progressively reduce the resistance to the outflow of fluid through the vane end groove from the coacting vane slot; and said inner port being positioned so that the degree of the registration of the inner port with each vane slot carrying a vane in said rotary direction through the outlet zone of the fluid working space reaches a maximum degree when the coacting vane is passing through a medial portion of said fluid outlet zone and is greatly reduced before the coacting vane passes beyond said fluid outlet zone.

17. A rotary vane fluid power unit comprising, in combination, a rotor, housing means encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having fluid inlet and outlet zones, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed within said respective vane slots for engagement with said cam surface, said housing means including means for supplying fluid to the intake zone of said pumping space, said housing means including fluid outlet means for releasing fluid from said outlet zone of said fluid working space, said fluid outlet means including means defining outlet passage space confronting one end of said rotor, each of said vanes defining in the axial end thereof adjacent said one end of said rotor a groove extending from the inner to the outer edge of the vane; said outlet passage space being shaped and being positioned relative to said working space outlet zone so that, upon turning of said rotor in a rotary direction which discharges fluid from said outlet zone, said end groove in each vane passing through said outlet zone establishes a communicating alinement with said outlet passage space which begins adjacent the periphery of the rotor and progresses inwardly to progressively reduce the re-

sistance to the outflow of fluid through the vane end groove from the coacting vane slot; and the position of said outlet passage space relative to said outlet zone being such that the inner portion of each slot carrying a vane in said rotary direction through said outlet zone moves into alinement with said passage space but passes out of alinement with said passage space before the coacting vane passes beyond said fluid outlet zone.

18. A rotary vane fluid power unit comprising, in combination, a rotor, housing means encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having fluid inlet and outlet zones, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed within said respective vane slots for engagement with said cam surface, a plurality of rotor reinforcing elements corresponding to said respective vane slots, each rotor reinforcing element extending between opposite sides of the corresponding vane slot and firmly coacting with portions of the rotor on opposite sides of the slot to effect mutual reinforcement of the rotor portions defining the slot at a position disposed outwardly of the inner extremity of the slot, each vane having a radially inner portion shaped to overlap the adjacent rotor reinforcing element for an extended distance when the vane is in its retracted position, said housing means including means for supplying fluid to the intake zone of said pumping space, said housing means including fluid outlet means for releasing fluid from said outlet zone of said fluid working space, said fluid outlet means including means defining outlet passage space confronting one end of said rotor, each of said vanes defining in the axial end thereof adjacent said one end of said rotor a groove extending from the inner edge to the outer edge of the vane; said outlet passage space being shaped and being positioned relative to said working space outlet zone so that, upon turning of said rotor in a rotary direction which discharges fluid from said outlet zone, said end groove in each vane passing through said outlet zone establishes a communicating alinement with said outlet passage space which begins adjacent the periphery of the rotor and progresses inwardly to progressively reduce the resistance to the outflow of fluid through the vane end groove from the coacting vane slot; and the position of said outlet passage space relative to said outlet zone being such that the inner portion of each slot carrying a vane in said rotary direction through said outlet zone moves into alinement with said passage space but passes out of alinement with said passage space before the coacting vane passes beyond said fluid outlet zone.

19. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space, said rotor defining an annular series of vane slots, a plurality of vanes slidably mounted in said respective slots to extend outwardly therefrom into engagement with said cam surface, a plurality of rotor reinforcing elements corresponding to said respective vane slots and being disposed within the limits of said slots along the axis of the rotor, each rotor reinforcing element extending outwardly a substantial distance beyond the inner extremity of the corresponding vane slot and extending between opposite sides of the slot in firmly coacting relation to portions of the rotor on opposite sides of the slot to effect mutual reinforcement of the rotor portions defining the slots, each vane having a radially inner portion shaped to overlap the adjacent rotor reinforcing element for an extended distance when the vane is in its retracted position, each vane having a radially outer portion which extends between and which is substantially flush with opposite ends of the adjacent portion of the rotor, each of said rotor reinforcing element defining a cylinder opening outwardly toward the opposing inner edge of the coacting vane, a plunger slidably mounted in each cylinder to act outwardly on the adjacent vane, means for supplying fluid under pressure to each cylinder to act on the plunger therein to urge the plunger and the coacting vane outwardly, and each vane having associated therewith means providing communication for fluid between the inner and outer edges of the vane.

20. A rotary vane fluid pump comprising, in combination, a rotor, means defining a cam surface encircling said rotor and defining therewith a pumping space having fluid inlet and outlet zones, fluid supply means for supplying fluid to said pumping space at said inlet zone thereof, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed in said respective slots for engagement with said cam surface, each of said vanes having an inner portion thereof defining a notch opening radially inward and having side edges diverging in a radially inward direction to inner extremities of the vane located adjacent opposite ends of the rotor, means on said rotor defining a plurality of protuberances corresponding to said respective slots, each protuberance being positioned with reference to its corresponding slot to extend outwardly into said notch in the coacting vane when the vane is in a retracted position; each protuberance having an outer edge confronting the inner edge of the corresponding vane and having a shape, as viewed in a section thereof taken axially with respect to the rotor, which conforms generally to the shape of the notch in the vane; each of said protuberances defining a cylinder therein, a plunger mounted in each cylinder to act outwardly on the adjacent vane, means for supplying operating fluid under pressure to said cylinders to urge said plungers and vanes outwardly, and said fluid supply means including means defining fluid supply passage spaces confronting opposite ends of said rotor in positions which register with the radially inward portions of the vane slots in the rotor as the slots move the coacting vanes through said inlet zone of said pumping space.

21. A rotary vane fluid power unit comprising, in combination, a rotor, housing means encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having fluid inlet and outlet zones, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor, a plurality of vanes slidably disposed within said respective vane slots for engagement with said cam surface, a plurality of rotor reinforcing elements corresponding to said respective vane slots, each rotor reinforcing element extending between opposite sides of the corresponding vane slot and firmly coacting with portions of the rotor on opposite sides of the slot to effect mutual reinforcement of the rotor portions defining the slot at a position disposed outwardly of the inner extremity of the slot, each vane having a radially inner portion shaped to overlap the adjacent rotor reinforcing element for an extended distance when the vane is in its retracted position, said housing means including means for supplying fluid to the intake zone of said pumping space, said housing means including fluid outlet means for releasing fluid from said outlet zone of said fluid working space, said fluid outlet means including means defining outlet passage space confronting one end of said rotor, and said outlet passage space having a position such that upon turning of said rotor to discharge fluid from said outlet zone of said working space each vane slot carrying a vane through the outlet zone of the working space is brought into an alinement with the passage space which alinement reaches a maximum value when the coating vane is passing through a medial portion of said fluid outlet zone and which is greatly reduced before the coacting vane passes beyond said fluid outlet zone.

22. A rotary vane fluid pump comprising, in combination, a rotor, means defining a cam surface encircling said rotor and defining therewith a pumping space having fluid

inlet and outlet zones, fluid supply means for supplying fluid to said pumping space at said inlet zone thereof, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor; the bottom of each vane slot, as viewed in an axial section of the rotor, having a truncated triangular shape which tapers from opposite ends of the rotor in a radially outward direction to a flatted outer extremity centrally located axially between opposite ends of the rotor; a plurality of vanes slidably disposed in said respective slots for engagement with said cam surface, each of said vanes having a radially inner edge positioned on the vane and shaped to extend into adjacent relation to and to conform to the bottom of the coacting slot when the vane is in a retracted position, and said fluid supply means including means defining fluid supply passage spaces confronting opposite ends of said rotor in positions which register with the radially inward portions of the vane slots in the rotor as the slots move the coacting vanes through said inlet zone of said pumping space so that fluid flows from said fluid supply spaces into the inner portions of each vane slot passing through said inlet zone and is urged radially outward by centrifugal force against the shaped inner edge of the adjacent vane to flow radially outward and axially inward along said inner edge of the vane to fill the vane slot inward of the vane as the vane moves outwardly.

23. A rotary vane fluid pump comprising, in combination, a rotor, means defining a cam surface encircling said rotor and defining therewith a pumping space having fluid inlet and outlet zones, fluid supply means for supplying fluid to said pumping space at said inlet zone thereof, said rotor defining an annular series of vane slots opening outwardly through the periphery of the rotor; the bottom of each vane slot, as viewed in an axial section of the rotor, having a shape which progressively narrows axially in a radially outward direction to an outer extremity centrally located axially between opposite ends of the rotor; a plurality of vanes slidably disposed in said respective slots for engagement with said cam surface and for in and out radial movements in the slots to follow said cam surface as said rotor rotates; each of said vanes defining a radially inner edge having a shape, as viewed in an axial section of the rotor, that conforms generally to the shape of the bottom of the coacting slot; and said fluid supply means including means defining fluid supply passage spaces confronting opposite ends of said rotor in positions which register with the radially inward portions of the vane slots in the rotor as the slots move the coacting vanes through said inlet zone of said pumping space so that fluid flows from said fluid supply spaces into the inner portions of each vane slot passing through said inlet zone and is urged radially outward by centrifugal force against the shaped inner edge of the adjacent vane which directs the fluid axially inward along said inner edge of the vane to fill the vane slot inward of the vane as the vane moves outwardly.

24. A rotary vane fluid power unit comprising, in combination, a rotor defining thereon two flat end face surfaces axially spaced apart and extending radially inward from the periphery of the rotor in concentric relation thereto, a housing encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space having spaced zones for admitting and discharging fluid, said rotor defining an annular series of outwardly open vane slots spaced apart by intervening sectors of the rotor, a plurality of vanes slidably mounted in said respective slots to extend outwardly therefrom into engagement with said cam surface, each vane being slidable in its slot between a retracted position and an extended position to effect continuous engagement of the outer maginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a recess extending between opposite sides of the vane and extending outwardly in the vane from the inner extremity of the vane, said rotor including a plurality of rotor reinforcing elements corresponding to said respective vane slots and occupying stationary positions with respect to the rotor in which the reinforcing elements extend radially outward for substantial distances into said recesses in said respective vanes when the latter are in their fully retracted positions, said rotor reinforcing elements each coacting with the two adjacent rotor sectors to transmit forces therebetween to effect by means of the reinforcing elements a mutual reinforcement of said intervening rotor sectors against applied bending loads, each of said rotor reinforcing elements defining a cylinder opening outwardly toward the opposing inner edge of the adjacent vane, a plunger slidably mounted in each of said cylinders to act outwardly on the inner edge of the adjacent vane, means including a pressure switching valve connecting said zones of said working space with said cylinders to supply fluid automatically from the zone under the higher fluid pressure to each cylinder to act on the plunger therein to urge the plunger and the coacting vane outwardly, each vane having associated therewith means providing continuous communication for fluid between the inner and outer edges of the vane, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is equal to the axial distance between said flat end face surfaces on the rotor, and each of said flat end face surfaces on the rotor extending continuously across the adjacent end of each rotor sector to the radially inner extremity thereof for the radial positions of the adjacent portions of the fully extended vanes.

25. A rotary vane fluid power unit comprising, in combination, a rotor defining thereon two flat end face surfaces axially spaced apart and extending radially inward from the periphery of the rotor in concentric relation thereto, a housing encasing said rotor and including means defining a cam surface encircling said rotor and defining therewith a fluid working space, said rotor defiing an annular series of outwardly open vane slots spaced apart by intervening sectors of the rotor, a plurality of vanes slidably mounted in said respective slots to extend outwardly therefrom into engagement with said cam surface, each vane beig slidable in its slot between a retracted position and an extended position to effect continuous engagement of the outer marginal edge of the vane with said cam surface upon rotation of the rotor, each vane having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a recess extending between opposite sides of the vane and extending outwardly in the vane from the inner extremity of the vane, said rotor including a plurality of rotor reinforcing elements corresponding to said respective vane slots and occupying stationary positions with respect to the rotor in which the reinforcing elements extend radially outward for substantial distances into said recesses in said respective vanes when the latter are in their fully retracted positions, said rotor reinforcing elements each coacting with the two adjacent rotor sectors to transmit forces therebetween to effect by means of the reinforcing elements a mutual reinforcement of said intervening rotor sectors against applied bending loads, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is equal to the axial distance between said flat end face surfaces on the rotor, and each of said flat end face surfaces on the rotor extending continuously across the adjacent end of each rotor sector to

the radially inner extremity of the rotor sector from the radial positions of the adjacent portions of the fully extended vanes.

26. A rotary vane fluid power unit comprising, in combination, a rotor, a housing encasing said rotor and including means defining a cam surface encircling said rotor, said cam surface being shaped and positioned in relation to the periphery of said rotor to define therebetween a working space for fluid, said housing defining flow passages communicating with said working space at spaced positions therealong, said rotor defining an annular series of vane slots therein opening outwardly through the periphery of the rotor and being separated by intervening sectors of the rotor, an annular series of circumferentially spaced vane units corresponding in number to and being formed in part by said respective vane slots, each vane unit including a vane slidably disposed in its corresponding slot in said rotor between a retracted position and a fully extended position to effect continuous engagement of the outer edge of the vane with said cam surface upon rotation of the rotor, the vane of each vane unit having an inner edge disposed within the corresponding vane slot for all positions of the vane and being shaped to define in an inner portion of the vane a notch extending between opposite sides of the vane and extending outwardly in the vane from the inner extremity of the vane, said rotor including a plurality of rotor reinforcing elements corresponding to said respective vane slots and occupying stationary positions with respect to the rotor in which the reinforcing elements extend radially outward for substantial distances into said recesses in said vanes of said respective vane units when the vanes are in their retracted positions, said rotor reinforcing elements each coacting with the two adjacent rotor sectors to transmit forces therebetween to effect by means of the reinforcing elements a mutual reinforcement of said intervening rotor sectors against applied bending loads, the portion of each intervening rotor sector located radially inward of the radial positions of the inner edges of the fully extended adjacent vanes being of solid construction that is impervious to the passage of fluid therethrough between the adjacent slots and having a minimum axial width that is at least substantially equal to the maximum axial width of the portion of each adjacent vane that extends outwardly from the periphery of the rotor when the vane is fully extended, each vane unit defining first and second vane biasing surfaces associated with the vane of the unit and being continuously exposed by the vane unit to the pressure of fluid in the interspace adjacent the vane between said cam surface, said first biasing surface for each vane unit being oriented so that the force thereon of fluid pressure urges the corresponding vane inwardly, said second biasing surface of each unit being oriented so that the force of fluid pressure thereon urges the corresponding vane outwardly, each vane unit defining a third biasing surface associated with the corresponding vane and oriented so that the force of fluid pressure on said third surface urges the vane outwardly, each vane unit including means associated therewith to isolate said third biasing surface thereof from direct communication with said second biasing surface of the unit, means associated with each unit for supplying to said third biasing surface thereof fluid under high pressure from a high pressure portion of said working space for fluid, each vane unit including spring means stressed to urge the corresponding vane outwardly in its slot, said spring means for each vane having a movable power applying portion which acts on the vane and moves in and out with the vane as the vane moves in and out in its slot, and said spring means for each vane having a support portion which reacts on the rotor to transmit thereto the reaction of the adjacent vane on the spring means and which is stationary with respect to the rotor so that the spring means is flexed and stores energy upon inward movement of the vane and subsequently releases energy by relaxation to extend the vane.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,257,958 June 28, 1966

Cecil E. Adams et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 39, for "inwardly" read -- inward --; column 3, line 25, for "but" read -- and --; column 4, line 11, for "end" read -- ends --; column 7, line 29, for "efftctive" read -- effective --; column 10, line 7, for "afluid" read -- a fluid --; column 11, line 15, for "theinner" read -- the inner --; line 32, for "refernce" read -- reference --; line 73, for "valve" read -- vane --; column 12, line 2, for "liquid" read -- fluid --; line 38, for "van" read -- vane --; line 49, for "surface" read -- surfaces --; line 60, for "throtting" read -- throttling --; line 70, for "engagemednt" read -- engagement --; lines 72 and 73, for "coating" read -- coacting --; column 13, line 38, after "vane" insert -- edge --; line 47, for "check" read -- cheek --; line 51, for "port" read -- ports --; column 14, line 38, before "reference" insert -- same --; line 55, after "vane" insert -- as the vane --; column 15, line 3 for "betwen" read -- between --; line 41, for "thereupon" read -- thereon --; column 17, line 59, for "vanes" read -- vane --; column 19, line 45, after "from" insert -- the --; column 20, line 68, for "vance" read -- vane --; column 21, line 71, after "vanes" insert -- being --; column 22, line 42, after "flowing" insert -- communication from opposite ends of the rotor through the inner portion of the vane slot to said outwardly offset medial portion of the inner edge of the vane --; column 25, line 74, for "element" read -- elements --; column 26, line 69, for "coating" read -- coacting --; column 28, line 42, for "defiing" read -- defining --; line 47, for "beig" read -- being --; column 30, line 5, after "between" insert -- said rotor and --.

Signed and sealed this 1st day of August 1967.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

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Commissioner of Patents