April 21, 1964 G. L. MALAN 3,129,925

VIBRATOR WITH SEPARATE BEARING AND COMPARTMENT-FORMING SURFACES

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FIG. 1

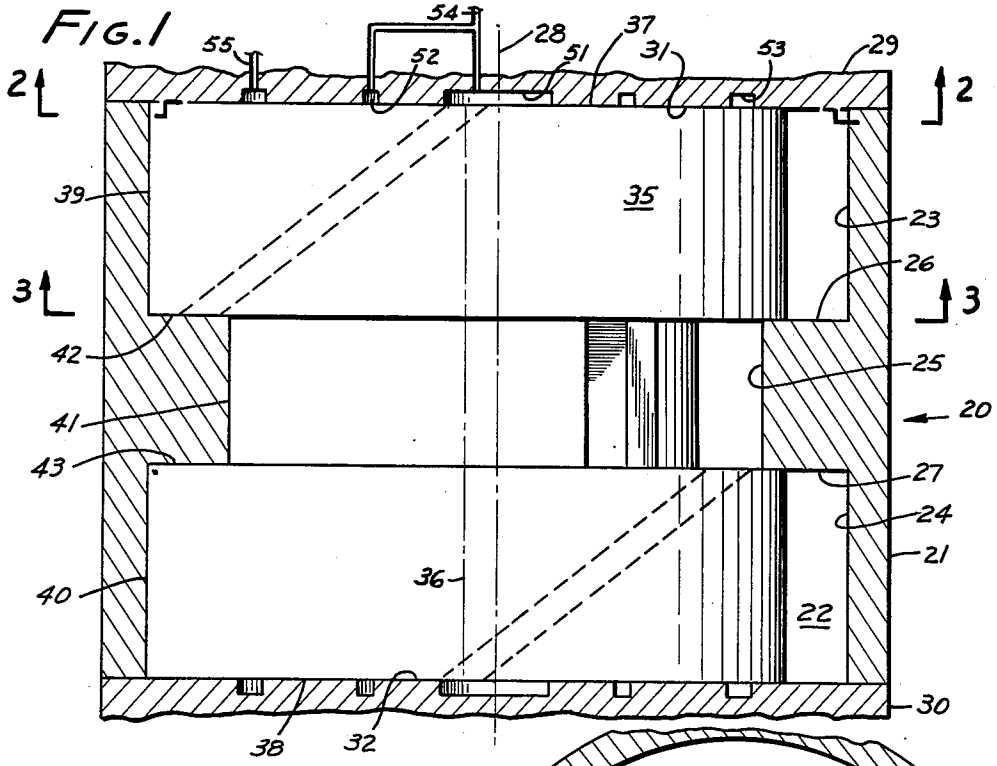


FIG. 2

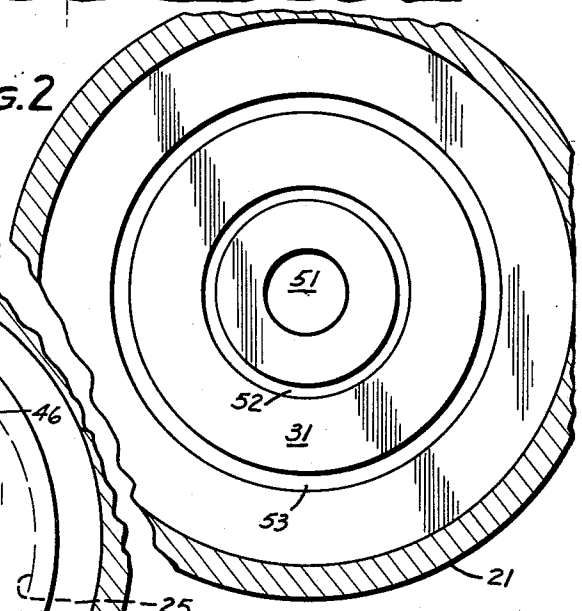
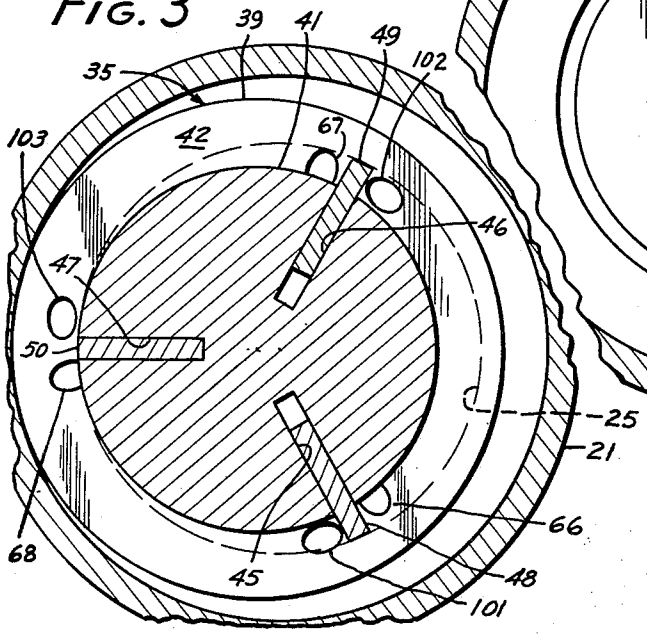


FIG. 3



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FIG. 4

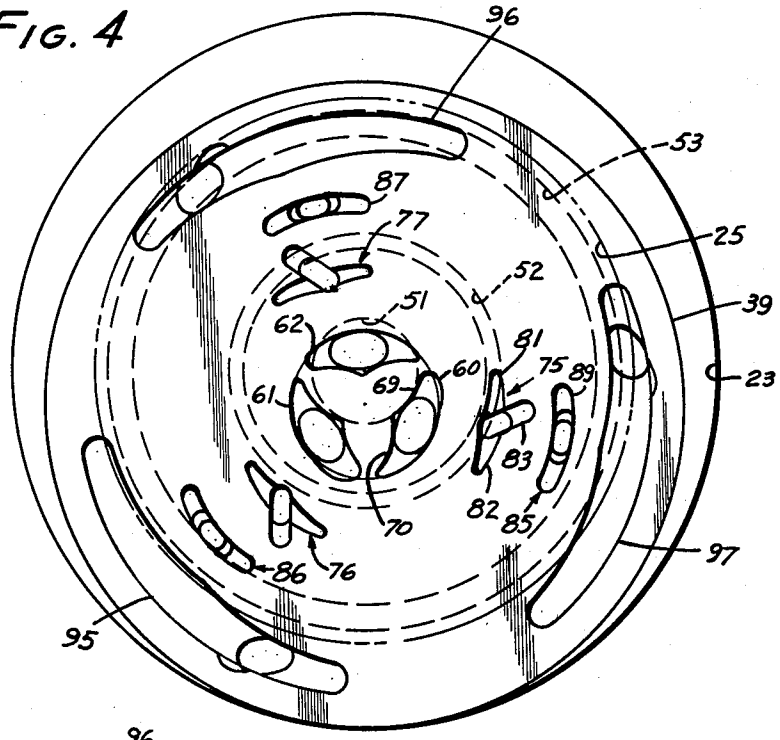
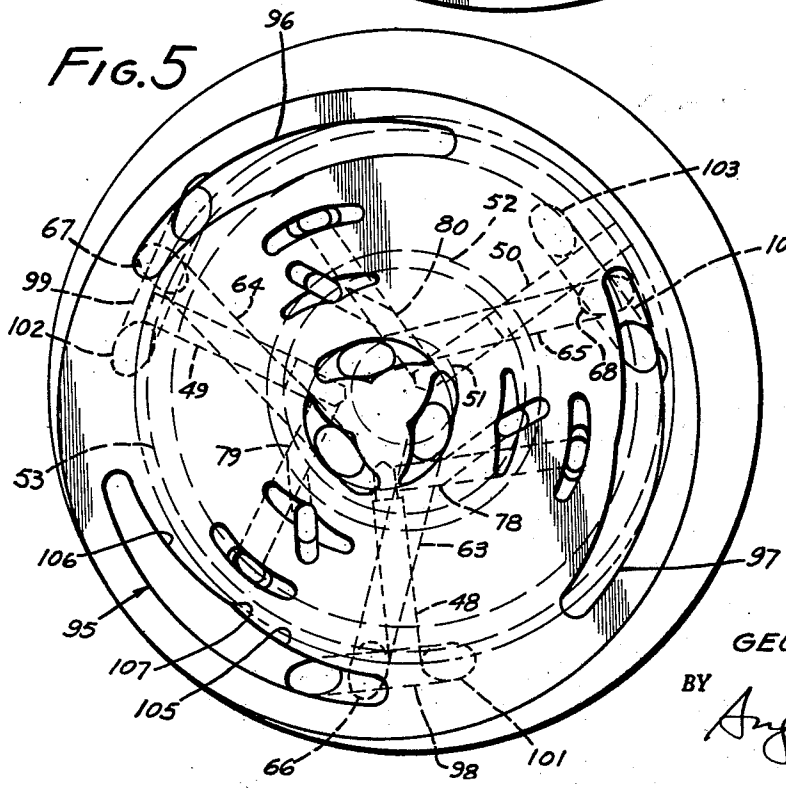


FIG. 5



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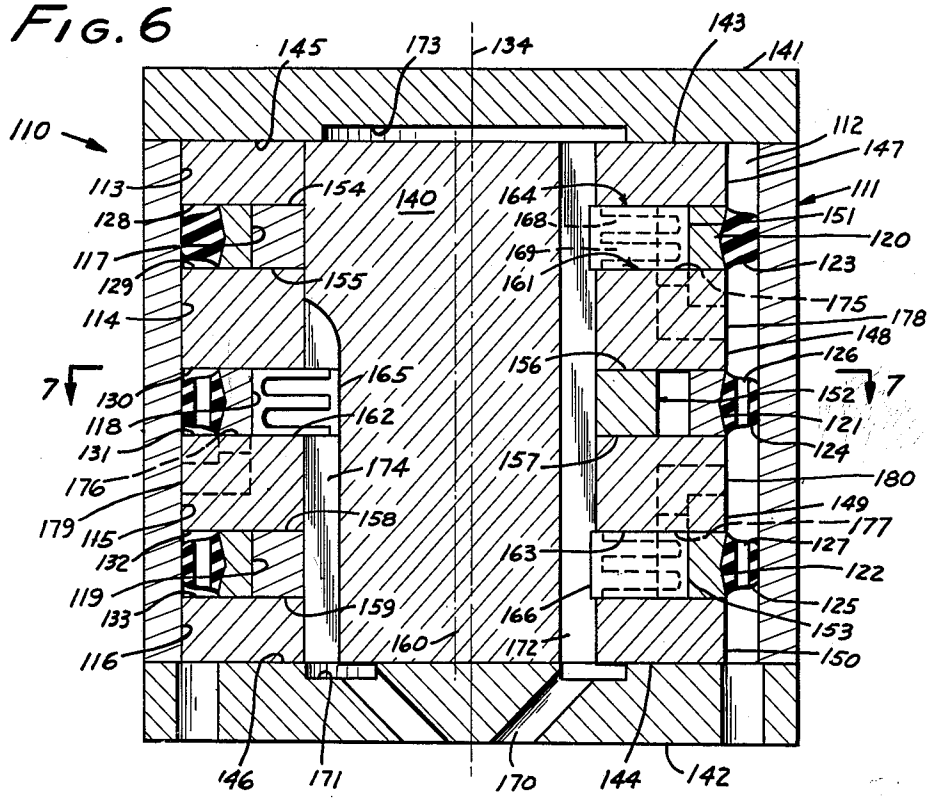
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FIG. 6



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FIG. 7

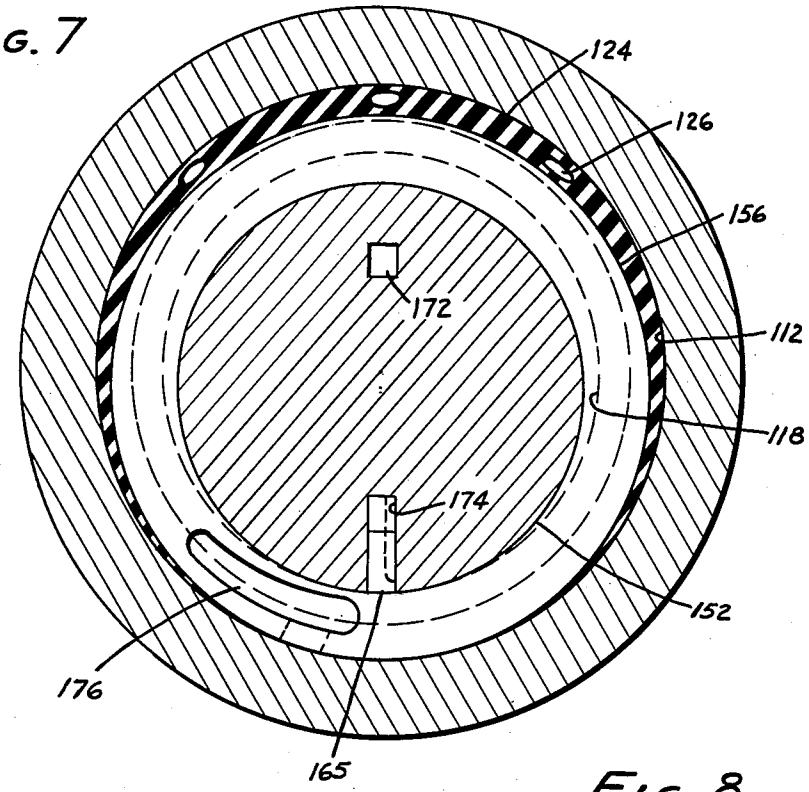


FIG. 8

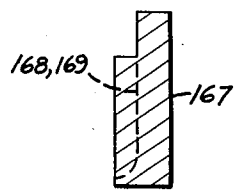


FIG. 9

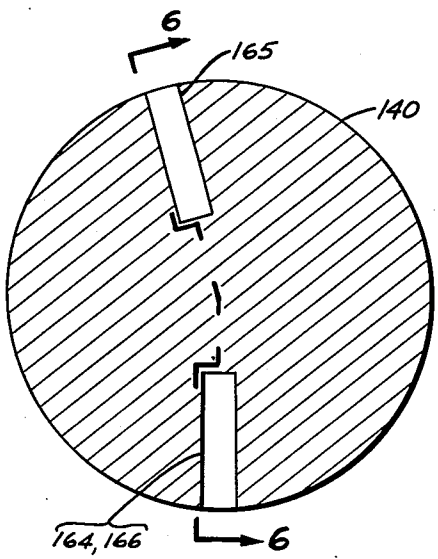
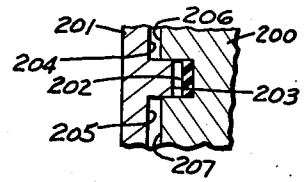


FIG. 10



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Patented Apr. 21, 1964

3,129,925

VIBRATOR WITH SEPARATE BEARING AND COMPARTMENT-FORMING SURFACES

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Filed Apr. 5, 1962, Ser. No. 185,479
18 Claims. (Cl. 259—1)

This invention relates to vibrators of the type wherein a free rotor rolls around the inside of a case to create eccentric forces useful for various purposes, such as the distribution of wet concrete in forms.

Vibrators of this type are known in the art, among which are those shown in United States patents to Malan Nos. 2,187,088, 2,743,090, and 2,891,775. These vibrators are in every day use throughout the world, usually using compressed air for power.

A characteristic feature of these vibrators is their use of a free rotor (free in the sense that it does not rotate around a fixed axis, such as a shaft), which carries an extensible vane. The vane divides up the region between the case and the rotor into compartments which can periodically be placed under greater and lesser fluid pressures to impel the rotor to roll along a cylindrical race formed in the case. In the past, the race along which the rotor rolled, and the peripheral bearing surface of the rotor which contacted the race were both straight cylinders which extended from end to end of the rotor. In such an arrangement, a volume of fluid had to be taken into the case and expelled from it each trip of the rotor around the race equal to the difference between the volume of the race and that of the rotor. While this is not intolerable when a gas is used for power, it is such a large rate of flow at operating speeds of perhaps 12,000 r.p.m., that it has not been feasible to use liquids under pressure for power.

There is a growing interest in the possibility of using liquids under pressure for powering vibrators. If run at relatively high pressures, compared to the 70–100 p.s.i.g. pressures commonly used for air, significant operating advantages can be obtained, but not if such large volumes have to be run through the vibrator. Accordingly, it is an object of this invention to provide vibrator improvements which require a lesser volume through-put of fluid to operate a vibrator of a given size, and thereby to render feasible the operation of the vibrator with a liquid under pressure for power. However, the improvements also result in significant increases in efficiency when the vibrator is run with compressed air for power, so that the utility of the improvements is not limited to operation with liquids.

Still another problem which arises in conventional vibrators is the tendency of the rotor to wear relatively rapidly at the edge of the slot in which the vane reciprocates, thereby throwing the rotor out of round. Such wear requires that the rotor be reground to a round configuration. To do this requires shipping the vibrator from the job to the shop and return, together with expensive machining and custom-fitting operations. Any technique which can reduce the wear at the most vulnerable points on the rotor constitutes an important economy.

Accordingly, it is another object of this invention to provide vibrator improvements wherein the major proportion of rotor wear occurs on continuous, uninterrupted surfaces, instead of at the edges of the slots. This minimizes both total wear on the rotor, and also wear at differential rates on its surface.

Yet another problem arises in the design and construction of conventional vibrators, because of their inherent geometry. In the vibrations shown in Patents Nos. 2,187,088 and 2,743,090, for example, all intake and exhaust

control is accomplished at the end of the rotor by coaction between ports in the rotor and in end plates carried by the case. It is necessary to provide for power to extend the vanes, and to expand compartments at the periphery of the rotor. It is also necessary to provide connections to vent the inner ends of the vanes, and to vent the compartments. These functions must occur in a timed sequence for each vane. There is therefore required a substantial number of grooves and ports, whose position is dictated by the basic geometry of the device, and there is little or no freedom to adjust the timing or shift the location of these features because to do so would often cause overlap of ports each having a different purpose, which is intolerable. For example, it is not now possible to arrange for using the expansibility of a compressed gas in powering the device. Instead, in most vibrators, only a minor portion of the total pressure drop occurs in the vibrator itself, which constitutes a waste of a substantial portion of the energy in the compressed gas.

It is an object of this invention to provide valving means between the rotor and the case at locations other than the end of the rotor, and thereby remove from that area substantial ports and the like which otherwise would be present, and whose presence would limit the freedom to put other ports in the same place. Improved function can therefore be derived from the freedom to locate valving elements with greater selectivity. By providing a plurality of cooperating interacting valving surfaces, the inherent design limitations of each set are drastically alleviated.

A fluid-powered vibrator according to this invention comprises a case having an internal cylindrical race with a first diameter and a central axis. A cylindrical compartment-forming surface in the case has a second diameter which differs by an increment from the first diameter, the race and compartment-forming surface being concentric.

A rotor within the case has a central axis, the axes of the rotor and the race being parallel and normally displaced from one another. A cylindrical bearing surface on the rotor is adapted to roll along the race, the bearing surface having a third diameter. A cylindrical compartment-forming surface on the rotor has a fourth diameter which differs from the third diameter by substantially the same increment, as exists between the first and second diameters, the bearing surface and the compartment-forming surface on the rotor being concentric.

A vane is carried by, is reciprocable in, is extensible beyond, and is axially coextensive with, the compartment-forming surface of the rotor, and it thereby is adapted to form a compartment between the vane and the two compartment-forming surfaces. Fluid supply and exhaust means are provided for causing rolling movement of the rotor within the case by periodically placing compartments under greater and lesser pressures, the race and bearing surfaces being in constant rolling contact with each other.

According to a preferred but optional feature of the invention, a first and a second flat annular shoulder lie normal to the axes of the rotor and race, and respectively interconnect the race to the compartment-forming surface in the case, and the bearing surface to the compartment-forming surface on the rotor, these shoulders making a sliding, fluid sealing fit with each other, and thereby providing additional valving surfaces.

According to still another preferred but optional feature of the invention, the race is provided in such form that it is resilient or yieldable, whereby the major proportion of the force transfer from the rotor to the case occurs between a continuous, unbroken race and bearing

surface, thereby eliminating a principal source of differential wear rates.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is a side elevation, partly in cutaway cross-section showing the presently preferred embodiment of the invention;

FIGS. 2 and 3 are cross-sections taken at lines 2—2 and 3—3, respectively, in FIG. 1;

FIGS. 4 and 5 are end views of the rotor of FIG. 1 shown in two different operating positions, with pertinent elements of the case overlaid for indicating the operation of the device;

FIG. 6 is a side elevation, partly in cutaway cross-section, showing another embodiment of the invention;

FIG. 7 is a cross-section taken at line 7—7 of FIG. 6;

FIG. 8 is a side view of a vane used in the device of FIG. 6;

FIG. 9 is a schematic illustration of a phase relationship between vanes in the device of FIG. 6; and

FIG. 10 is a modification of either of the devices of FIGS. 1 and 6.

FIGS. 1–5 show a vibrator **20** which includes a case **21** having an internal rotor cavity **22**. The rotor cavity is bounded in part by a pair of internal cylindrical races **23**, **24** having a first diameter. Between the races there is an internal cylindrical compartment-forming surface **25** having a second diameter. These diameters differ by an increment.

Flat planar shoulders **26**, **27**, respectively connect races **23** and **24** with compartment-forming surface **25**. The rotor cavity has a central axis **28** on which surfaces **23**, **24** and **25** are concentric and to which shoulders **26** and **27** lie normal.

End plates **29**, **30**, respectively include planar surfaces **31**, **32**, which also lie normal to central axis **28**. The end plates complete the enclosure of the rotor cavity.

A rotor **35** with a central axis **36** fits within the rotor cavity. It has lesser lateral (radial) dimensions than the respective portions of the rotor cavity walls. Two planar rotor end surfaces **37**, **38** are disposed normal to axis **36**. Because axes **28** and **36** are parallel, surfaces **31**, **32**, **37** and **38** are also parallel.

The axial spacing between rotor end surfaces **37** and **38** is substantially equal to the spacing between surfaces **31** and **32** less a small amount sufficient only to permit the adjacent ones of the end surfaces to make a close fitting, fluid-sealing, slidable contact with each other. Ordinarily this clearance will be no more than 0.001; and is adjusted by tightening up on the end plates until the desired operation of the rotor under power results.

The peripheral wall of the rotor is bounded by a pair of cylindrical bearing surfaces **39**, **40** having a third diameter, and a cylindrical compartment-forming surface **41** having a fourth diameter.

The third and fourth diameters differ by the same increment as the first and second, and in the same algebraic sense, the second and fourth being the lesser. The reverse relationship is also within the invention, where the second and fourth diameters are the larger, but again, the sense of their difference is the same. For example, the second diameter is never larger than the first while the fourth diameter is less than the third.

Two planar shoulders **42**, **43**, respectively connect bearing surfaces **39** and **40** to compartment-forming surface **41**. The axial spacing between shoulders **42** and **43** is substantially equal to the axial spacing between shoulders **26** and **27**. Adjacent members of these pairs of shoulders therefore form a fluid-sealing, sliding fit with each other, the clearances being of the same order as that between the rotor and the end plates.

The rotor has three radially extending vane recesses **45**, **46**, **47** spaced 120° apart, which open on the compartment-forming surface **41**. These slots are axially co-

extensive with surface **41**, and are parallel to axis **36**. Vanes **48**, **49**, **50** are respectively disposed in recesses **45**, **46** and **47**, and are longer than the difference in diameter between the compartment-forming surfaces, that is longer than the movement, so that they will always be reciprocably disposed in, and extensible beyond compartment-forming surface **41**. They are also axially coextensive with surface **41**. These vanes are therefore adapted to form compartments between surfaces **25** and **41**. Compartment-forming surface **25** is overlaid in dashed line in FIG. 3 to show its relationship to the vanes.

The rotor is caused to roll around the inside of the case by force exerted against surface **25**. The force is exerted by the vanes, and also by fluid under alternate conditions of higher and lower pressures introduced into the compartments formed by the vanes and between the compartment-forming surfaces.

At this juncture, the necessary valving and passages for operating the vibrator will be described. It will be evident that these passages and ports can be made by drilling into the rotor or case from the outside, and plugging off the unused segments of the drilled passages as appropriate.

The supply of fluid to the inside surfaces of the end plates will first be disclosed. There is a pressure supply port **51** centrally disposed in either or both of the end plates. It is customary, however, to provide ports with substantially equal pressures and areas in both ends of these devices in order to maintain as equal axial pressure loads on the rotor as possible, thereby minimizing friction at the end plates. Therefore, although ports for only one end of the rotor and for only one end plate will be described in detail, it will be understood that their mirror images will usually be, and in the illustrated embodiment are, provided in the other rotor end and end plate.

An annular pressure supply port **52** is formed concentric with port **51**. It has a large diameter, and is disposed radially outward therefrom. An annular exhaust port **53** surrounds ports **51** and **52**. Ports **52** and **53** are annular rings, while port **51** is an open circular port. All are concentric on the central axis of the rotor cavity.

Pressure conduit **54** is connected to ports **51** and **52** for conveying fluid under pressure to the pressure supply ports. Exhaust condit **55** is connected to port **53** for conveying exhaust fluid from the exhaust port. The conduits pass through the case. Similar conduits can be provided for end plate **30**, or passages may be formed in the case connecting like ports in both end plates to conduits **54** and **55**.

As for passages and ports in the rotor, only those having coaction with end plate **29** will be described in detail. It being again understood that the mirror image exists in the rotor and at the lower end thereof, in the preferred embodiment of the invention so that the supply is to both sides of the rotor, thereby providing for maximum fluid-flow passages and for a fluid balance rotor inside the case.

Rotor end surface **37** (see FIGS. 4 and 5) includes three compartment supply ports **60**, **61**, **62** which are spaced 120° apart. They feed through compartment supply passages **63**, **64**, **65**, respectively, to openings **66**, **67**, **68**. These openings are disposed in the rotor shoulders angularly adjacent to the clockwise side of their respective vanes so that they will supply pressure immediately adjacent to the vane. In operation, clockwise refers to the side of the vane which the line of tangency of the rotor and case reaches after it passes the vane, in the sense of FIG. 4. The openings could, if desired, be formed in compartment-forming surface **41** instead, at the same angular location. However, such alternate arrangement tends to cause the passage to have a more complicated course through the rotor, which is less desirable than a straight drilled passage. These openings

are, in either arrangement, so disposed and arranged as to provide fluid under pressure to a compartment formed immediately clockwise from their respective vanes.

Compartment supply ports 60, 61 and 62 are all identical, and therefore only port 60 will be described in detail. It is formed with an initial boundary edge 69 and a cut-off boundary edge 70 which respectively overlap the edge of central pressure supply port 51 at coordinated times to be described below. Vane extension ports 75, 76, 77 are formed 120° apart in the end of the rotor, and are for the purpose of respectively feeding pressure to the inner ends of vane recesses 45, 46, 47. Vane extension ports 75, 76 and 77 in the rotor end are connected to the inside ends of their respective vane recesses by vane passages 78, 79, 80.

Ports 75, 76 and 77 are all identical, and therefore only port 75 will be described in detail. Port 75 has three wings 81, 82, 83 whose edges are so disposed and arranged as to overlap annular pressure supply port 52 at coordinated periods of time to be discussed below, so as to maintain the inner edge of the respective vane under pressure when overlap occurs.

Vane retraction ports 85, 86, 87 are formed 120° apart in the rotor end for the purpose of venting the inner edges of the vanes at coordinated times. Vane ports 85, 86 and 87, respectively connect to vane passages 78, 79 and 80. Port 85 is typical of all the vane retraction ports. It includes a boundary edge 89 adapted to periodically overlap the edge of annular exhaust port 53.

Three compartment exhaust ports 95, 96, 97 are spaced 120° apart in rotor end surface 37. They connect through compartment exhaust passages 98, 99, 100, respectively, to the compartments immediately counter-clockwise of respective vanes 48, 49, 50. The connection is by means of openings 101, 102, 103, respectively, which are formed in shoulder 42. The openings and the passages may conveniently be formed by drilling into the rotor at the proper angle to form a passage opening onto the shoulder as shown, each entering its respective compartment exhaust port.

All of compartment exhaust ports 95, 96 and 97 are identical, and therefore only exhaust port 95 will be described in detail. It includes an initial boundary edge 105 and a cut-off boundary edge 106, which boundary edge join each other at point 107. Point 107 is located where it will be spaced outwardly of the annular exhaust port 53 when the tangent point of the rotor and the case is on a line from the tangent point to the central axis of the rotor. Both of edges 105 and 106 have substantially the same radius of curvature as the outer edge of annular exhaust port 53.

The embodiment of FIGS. 6–9 will now be described. This vibrator 110 includes a case 111 having a rotor cavity 112. Four internal cylindrical races 113, 114, 115, 116 are formed inside the case. Three internal cylindrical compartment-forming surfaces 117, 118, 119 are formed between the races. In this embodiment the compartment-forming surfaces on the case are resilient in nature. The resilience in the illustrated embodiment is attained by forming the surfaces on metallic rings 120, 121 and 122 which are not themselves resilient, but which are supported to the inside wall of the case by O-rings 123, 124, 125 which are made of resilient elastic material. O-rings 124, 125 have a plurality of exhaust passages 126, 127 therethrough. The effect of the support given by the resilient O-rings is to render the surface of the rings themselves resiliently yieldable because a force exerted against them can cause the compartment-forming surface to move toward the adjacent wall of the case. This is the equivalent of an inherently resilient surface, which could be used instead, such as by making rings 120, 121 and 122 of a resilient material, and mounting them directly to the case. Such a resilient arrangement may be provided for compartment-forming surface 25 in FIG. 1, instead of the unyielding surface shown therein. The substitution of the respective elements from FIG. 6 to FIG. 1 will be evident to the skilled person.

Flat planar shoulders 128, 129, 130, 131, 132 and 133 are formed at opposite sides of rings 120—122, thereby forming surfaces which lie normal to central axis 134 of the case and around which the races and the case's compartment-forming surfaces are coaxial.

A rotor 140 having lesser lateral dimensions than the corresponding regions of the rotor cavity, is placed inside the rotor cavity where it lies between end plates 141, 142 which complete the enclosure of the rotor cavity. The rotor includes a pair of rotor end surfaces 143, 144 which are axially spaced apart by substantially the same distance as the planar surfaces 145, 146 of the end plate with just enough clearance between the rotor and these surfaces that a fluid-sealing, slidable movement can take place without excessive friction.

The rotor includes four bearing surfaces 147, 148, 149, 150. Three compartment-forming surfaces 151, 152, 153 are formed between adjacent pairs of the bearing surfaces. Flat planar shoulders 154, 155, 156, 157, 158 and 159 lie normal to the central axis 160 of the rotor and form boundaries for the bearing surfaces and the compartment-forming surfaces on the rotor which surfaces are also coaxial around central axis 160.

The races, bearing surfaces, and compartment-forming surfaces have the same relationship as to diameters as in the embodiment of FIG. 1, differing by like increments between first and second, and third and fourth diameters, in the same algebraic sense.

Three vane recesses 161, 162, 163 are formed in the rotor. They extend radially outward in the rotor and open onto its compartment-forming surfaces, the recesses lying parallel to the axis and being coextensive with the axial length of the respective compartment-forming surface. Three vanes 164, 165, 166 are provided for recesses 161, 162, 163, respectively. Each vane has one flat side (FIG. 8) 167 and one side provided with slots 168, 169 (on vane 164, which is shown as an example of all of the vanes). The length of the vane is greater than the diametrical difference between the compartment-forming surfaces on the rotor and case so that the vane is reciprocable in the recess, extensible beyond it, and may remain in continuous contact with the opposite compartment-forming surface so as to form compartments on the opposite sides of it for purposes yet to be described.

Slots 168, 169 do not extend the full length of the slot but are of such a length, that as in the illustrated example of vane 164, they shut off fluid flow past the vane when the vane is substantially pressed back into its recess.

A pressure supply conduit 170 feeds pressure to a pressure supply port 171 in end plate 142. This port, which is annular, is in constant fluid communication with a pressure supply passage 172 which extends all the way through the rotor and feeds a pressure pad 173 in end plate 141 to balance the end loads on the rotor. It is possible, of course, to provide direct pressure conduits for pad 173, if desired, instead of the illustrated arrangement. There is another pressure supply passage 174 supplying pressure to vane 165. Passage 172 supplies vanes 164 and 166 so as to tend to keep the vanes biased outwardly at all times.

Three exhaust openings 175, 176, 177 are respectively formed in shoulders 155, 157, and 158. They are disposed at the side of the vane which does not carry the slots. Therefore, one side of each vane is adapted to be exposed to pressure except when the vane is substantially completely retracted into the rotor, and the other side of the vane is always connected to exhaust. Exhaust openings 175, 176, and 177 are respectively connected to exhaust passages 178, 179, 180, which open onto the races and are vented through the region adjacent the vents through the O-rings to the exhaust ports in the race, of which ports 126 and 127 are examples. In

practice, there will ordinarily be about ten to twelve of them arrayed in a ring-shaped pattern.

A feature which aids in starting the illustrated device resides in the fact that at least one of the vanes is angularly out of phase with respect to another. In the illustrated embodiment, it is advantageous for vanes 164 and 166 to be angularly aligned with each other so that they work simultaneously. Vane 165, however, will make an angle of about 15° with the diameter which passes through vanes 164 and 166. The effect of this placement of vane 165 is that a force resultant is exerted on the rotor tending to move it away from a centralized position as further disclosed below. The out-of-phase arrangement is illustrated schematically in FIG. 8, in which the positions of vanes 164, 165 and 166 are noted by lines.

The operation of the embodiment of FIGS. 1–4 will now be described. FIGS. 4 and 5 show two successive positions of the rotor as the rotor rotates around within the race. As illustrated, it climbs upward and to the left as it rolls from the position of FIG. 4 to that of FIG. 5. The first position, shown in FIG. 4, has the line of tangency between rotor and race directly in line with vane 48. In FIG. 5, the line of tangency has advanced half way between vanes 48 and 49. From these two positions, all others can readily be deduced. The line of tangency moves clockwise, assuming that the case does not rotate around its axis.

With initial reference to FIG. 4, it will be noted that compartment supply port 62 is in registration with pressure port 51, and that initial boundary 69 of compartment supply port 60 is about to come into registration with that port. Under these conditions, the compartment clockwise from vane 50 is under pressure which is applied through opening 68 to its respective compartment, and the compartment to be formed clockwise from vane 48 will shortly be supplied with pressure through opening 66.

It will be noted that one wing of vane extension port 77 is in registration with pressure port 52 and that vane retraction port 87 is out of registration with exhaust port 53. Vane 50 is therefore extended by pressure which enters through vane extension port 77. The compartment clockwise of vane 49 is not under pressure, because compartment supply port 61 is out of registration with pressure port 51, its cutoff boundary having just left an overlapped condition.

The initial boundary edge of compartment exhaust port 97 has just come into registration with exhaust port 53 which will exhaust the compartment counter-clockwise of vane 50 through opening 103. The compartment counterclockwise of vane 49 is exhausting from opening 102 through compartment exhaust port 96.

Vane 48 is about to be extended outwardly, because its vane extension port 75 is going into registration with pressure port 51. Its vane retraction port 85 has just moved out of registration with exhaust port 53. Also, with compartment supply port 60 about to overlap pressure port 51, vane 48 will be extended forming a compartment clockwise of it which is supplied with air through opening 66.

Sixty degrees later, that is, when the line of tangency has moved 60° around the rotor toward vane 49, the situation has changed as follows: compartment supply port 62 is still in registration with pressure port 51, but is moving in a relative direction which will move it out of registration, while compartment supply port 60 is moving into greater registration with port 51, and compartment supply port 61 is moving toward it.

Vane extension port 77 is still in registration with pressure port 52 but is moving in a direction to leave the same, but vane 50 is still held extended. Vane extension port 75 is still in registration with pressure port 52 and will remain so for a considerable time.

Both vane retraction ports 85 and 87 are out of registration with exhaust port 53, but vane retraction port 87 is moving toward it while port 85 is moving away from it. Port 86 is still in communication with it. Vane 49 therefore continues to be pressed back into its recess by contact with the race, while the other two vanes continue to be held outwardly.

Compartment exhaust ports 96 and 97 both overlap exhaust port 53, so that the compartments between vane 49 and the tangent line, and the compartment between vanes 49 and 50 are exhausting. The compartments between the tangent line and vane 48 is under pressure. This segment of rotor periphery could not go onto exhaust until the tangent line has passed opening 102, but before that happens, compartment exhaust port 96 has moved out of registration with groove 53. The compartment between vanes 48 and 50 will not exhaust until edge 105 of compartment exhaust port 95 overlaps exhaust port 53.

From the above it will be seen that compartments formed by the vanes, and by the vanes and the tangent line, sequentially are connected to pressure and exhaust, and that the pressure and exhaust regions "move" around the periphery of the rotor to roll the rotor in the case, the forces derived in this manner being supplemented by those exerted on the case by the vanes.

It will also be seen that the pairs of vane extension and retraction ports alternate in overlapping pressure and exhaust ports 52 and 53 to cause timed vane action.

It will be noted that the force reaction between the rotor and the case occurs substantially entirely between the race and bearing surface, because they are always in contact. The compartment-forming surfaces can even be formed with slight clearances, if desired, or made resilient in both embodiments, to make a light yielding contact which carries a negligible load, thereby reducing wear at the edges of the slots where the vanes extend from the compartment-forming surfaces.

The arrangement shown has the additional significant advantage that providing vanes of less than the full length of the rotor so that they do not require slit openings in the ends of the rotor where they interfere with the valving techniques shown, greater design freedom is attained. In this case, a greater period of pressure-on condition for each compartment is secured than in previously known valving techniques.

The operation of the device of FIGS. 6–8 will now be described. Initially, it will be noted that the same result of minimized wear on the vanes and the compartment-forming surfaces is attained here as in the embodiment of FIGS. 1–4, and for the same reason. It will also be observed that this embodiment includes three separate vibrator systems, two of which are in angular phase or alignment, and the third of which is angularly out of phase. Such an arrangement avoids the current situation in vibrators of this class where, with but a single vane in operation, or with a plurality, but all aligned, the vanes can push the rotor to a centralized position where it will stall under heavy loads. With the additional out-of-phase vane, there is a resultant force which tends to push the rotor off of that centralized position within the race, and the stalling is thereby overcome.

When pressure is introduced into pressure supply conduit 170, it is also introduced to pressure supply passages 172 and 174, where it continually keeps the vanes biased toward an extended position. All vanes are therefore extended as far as they can be at all times, the amount of extension being determined by the momentary spacing between opposing compartment-forming surfaces. When the relative position of the surfaces is that shown for vane 165, with the line of tangency aligned with the vane, there is no elevated pressure on any of the compartment-forming surfaces. However, there is the biased tendency of the vane to press outwardly, which it does. As soon as the vane moves out far enough so that its slots 168 and 169 pass pressure to one side of the vane, then there is a tendency for the rotor to move, because the rotor will, as soon as it gets into operation, remain tangent to the case, and thereby, with the vane, divide up the region between

the compartment-forming surfaces into two chambers, one connected to the pressure supply, and one to the exhaust.

The line of tangency therefore moves around the rotor as the rotor rolls in the case. As the line of tangency approaches the exhaust side of the vane, air therein is exhausted through the respective exhaust opening until the tangent point passes over it. Thereafter the sequence repeats itself.

It will be observed then, that the device of FIGS. 6–8 provides the aforementioned advantages of minimized wear on the operating surfaces, and also, by the provision of an angularly out-of-phase vane supplies a resultant force which prevents the rotor from attaining a centralized stalled position.

FIG. 10 illustrates that a resilient compartment-forming surface can be provided on the rotor, instead of on the case. It could be provided in addition to a resilient surface on the case, if desired. As illustrated, a rotor **200** and a case **201** include compartment-forming surfaces **202, 203**, respectively. There are also races **204, 205**, and bearing surfaces **206, 207**. The said surfaces and races are identical to those in the other embodiments, and the case and rotor of FIG. 10 represent those of either of the embodiments of FIGS. 1 and 6. Compartment-forming surface **202** is formed on a ring **207** of resilient material, such as rubber, bonded in the groove between bearing surfaces **206** and **207**. A metal facing (not shown) may be bonded to ring **207** on which surface **202** could be formed, if desired, so that actual contact could be metal-to-metal instead of metal-to-resilient material. The deflection of the resilient material is not especially large, because it is limited by the contact between the races and bearing surfaces, and only light contact, at the compartment-forming surfaces is usually desired. Therefore, the deflection and deformation of the resilient material is not large enough to interfere with the free movement of the vanes.

This invention is not to be limited by the embodiments shown in the drawings and described in the description which are given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. A fluid-powered vibrator comprising: a case having an internal cylindrical race with a first diameter and a central axis; a cylindrical compartment-forming surface on the inside of the case having a second diameter which differs by an increment from the first diameter, the race and compartment-forming surface being concentric; a rotor within the case having a central axis, the axes being parallel and normally displaced from one another; a cylindrical bearing surface on the rotor adapted to roll along the race, the bearing surface having a third diameter; a cylindrical compartment-forming surface on the rotor having a fourth diameter which differs from the third diameter by substantially the same increment, the bearing surface and the compartment-forming surface on the rotor being concentric; a vane carried by the rotor which is reciprocable within, extensible beyond, and axially coextensive with, the compartment-forming surface on the rotor, and thereby being adapted to form a compartment between the vane and the two compartment-forming surfaces; and fluid supply and exhaust means for causing rolling movement of the rotor within the case by periodically placing compartments under greater and lesser pressures, the race and bearing surfaces being in constant rolling contact with each other during said rolling movement.

2. A fluid-powered vibrator according to claim 1 in which a first and a second flat annular shoulder lie normal to the axes of the rotor and race, and respectively interconnect the race to the compartment-forming surface on the case, and the bearing surface to the compartment-forming surface on the rotor, said shoulders making a fluid sealing sliding fit with each other as the rotor rolls in the case.

3. A fluid-powered vibrator according to claim 2 in which a valving port is provided in one of said shoulders which is so disposed and arranged as to open onto a compartment formed between the compartment-forming surfaces in at least some positions of the rotor which occur when a radial line between the central axis of the rotor and the point of contact between the rotor and the race does not intersect said port.

4. A fluid-powered vibrator according to claim 1 in which there are provided two axially spaced-apart sets of said compartment-forming surfaces, and in which a race and a bearing surface extend axially between respective members of said sets of compartment-forming surfaces, a vane in one compartment-forming surface being angularly out of phase with a respective vane in the other compartment-forming surface.

5. A fluid-powered vibrator according to claim 1 in which the compartment-forming surface on the case is resilient, whereby the major proportion of eccentric force exerted on the case by rolling of the rotor within the case is applied at the race.

6. A fluid-powered vibrator according to claim 1 in which the compartment-forming surface on the case is formed on a ring of substantially non-resilient material, the ring being supported in the case by resilient means which render the ring yieldably resilient, whereby the major proportion of eccentric force exerted on the case by rolling of the rotor within the case is applied at the race.

7. A fluid-powered vibrator according to claim 1 in which the compartment-forming surfaces lie between respective members of two sets of races and bearing surfaces.

8. A fluid-powered vibrator comprising: a case having an internal cylindrical race with a first diameter and a central axis; a cylindrical compartment-forming surface on the inside of the case having a second diameter which differs by an increment from the first diameter, the race and compartment-forming surface being concentric and forming a rotor cavity; an end plate lying at each end of the cavity and closing its respective end, each end plate including a planar surface facing into the rotor cavity, and lying normal to the central axis; a rotor within the rotor cavity having a central axis, the axes being parallel and normally displaced from one another; a planar rotor end surface at each end of the rotor lying normal to the central axis of the rotor, the axial spacing between the rotor end surfaces being substantially equal to the axial spacing between the planar end plate surfaces, whereby the end plate and rotor end surfaces are adapted to make a sliding, fluid-sealing fit with each other; a cylindrical bearing surface on the rotor adapted to roll along the race, the bearing surface having a third diameter; a cylindrical compartment-forming surface on the rotor having a fourth diameter which differs from the third diameter by substantially the same increment, the bearing surface and the compartment-forming surface on the rotor being concentric; a vane carried by the rotor which is reciprocable within, extensible beyond, and axially coextensive with, the compartment-forming surface on the rotor, and thereby being adapted to form a compartment between the vane and the two compartment-forming surfaces; a pressure inlet passage through the case; a first pressure supply port in one of the end plate surfaces in fluid communication with the pressure inlet passage; a second pressure supply port in the rotor end surface which faces the first pressure supply port, said pressure supply ports being so disposed and arranged as to remain in communication with each other at all positions wherein the bearing surface and race are in contact with each other; a pressure supply passage in fluid communication with the second pressure supply port and with the vane; a compartment supply passage adapted to interconnect the second pressure port and the compartment-forming surfaces in at least some positions of the rotor in the case; and exhaust port means adapted to interconnect a compartment between the com-

partment-forming surfaces in at least some positions of the rotor in the case with the outside of the case, the race and bearing surfaces being in constant rolling contact with each other during rolling movement of the rotor within the case.

9. A fluid-powered vibrator according to claim 8 in which a first and a second flat annular shoulder lie normal to the axes of the rotor and race, and respectively interconnect the race to the compartment-forming surface in the case, and the bearing surface to the compartment-forming surface on the rotor, said shoulders making a fluid sealing sliding fit with each other as the rotor rolls in the case.

10. A fluid-powered vibrator according to claim 9 in which the exhaust port means opens in one of said shoulders, and is so disposed and arranged as to open onto a compartment formed between the compartment-forming surfaces in at least some positions of the rotor which occur when a radial line between the central axis of the rotor and the point of contact between the rotor and the race does not intersect said port.

11. A fluid-powered vibrator according to claim 9 in which at least some of said passages open onto the shoulders whereby they periodically open onto a respective compartment to accomplish a valving action.

12. A fluid-powered vibrator according to claim 10 in which there are provided two axially spaced-apart sets of said compartment-forming surfaces, and in which a race and a bearing surface extend axially between respective members of said sets of compartment-forming surfaces, a vane in one compartment-forming surface being angularly out of phase with a respective vane in the other compartment-forming surface.

13. A fluid-powered vibrator according to claim 10 in which the compartment-forming surface on the case is formed on a first ring of substantially non-resilient material, the first ring being supported in the case by a second ring, which is made of resilient material, between the case and the first ring, there being exhaust passages through the second ring, the second ring rendering the first ring yieldably resilient, whereby the major proportion of eccentric force exerted on the case by rolling of the rotor within the case is applied at the race.

14. A fluid-powered vibrator according to claim 13 in which the compartment-forming surfaces lie between respective members of two sets of races and bearing surfaces.

15. A fluid-powered vibrator comprising: a case having an internal cylindrical race with a first diameter and a central axis; a cylindrical compartment-forming surface on the inside of the case having a second diameter which differs by an increment from the first diameter, the race and compartment-forming surface being concentric, and forming a rotor cavity; an end plate lying at each end of the cavity and closing its respective ends, each end plate including a planar surface facing into the rotor cavity, and lying normal to the central axis, a rotor within the rotor cavity having a central axis, the axes being parallel and normally displaced from one another; a planar rotor end surface at each end of the rotor lying normal to the central axis of the rotor, the axial spacing between the rotor end surfaces being substantially equal to the axial spacing between the planar end plate surfaces, whereby the end plate and rotor end surfaces are adapted to make a sliding, fluid sealing fit with each other; a cylindrical bearing surface on the rotor adapted to roll along the race, the bearing surface having a third diameter; a cylindrical compartment-forming surface on the rotor having a fourth diameter which differs from the third diameter by substantially the same increment and in the same algebraic sense, the bearing surface and the compartment-forming surface on the rotor being concentric; a plurality of angularly spaced-apart vanes carried by the rotor which are reciprocable within, extensible beyond, and axially coextensive with, the compartment-forming surface on the rotor, and thereby being adapted to form respective compartments between the two compartment-forming surfaces; a pressure inlet passage and an exhaust passage through the case; a first and a second pressure supply port in one of the end plate surfaces in fluid communication with the pressure inlet passage; an exhaust port in one of the end plate surfaces in fluid communication with the exhaust passage; the pressure supply ports and the exhaust port being concentric, the second pressure port and exhaust port being annular grooves; a vane extension port and a vane retraction port for each vane, disposed in the end of the rotor adjacent said end plate surface, and adapted to periodically register with the second pressure port and the exhaust port, respectively; a compartment supply port for each vane so disposed and arranged in an end of the rotor as to periodically register with the first pressure port; a compartment supply passage connecting a compartment adjacent to the respective vane with its respective compartment supply port; a compartment exhaust passage adjacent to each vane and facing into a compartment on the opposite side of the respective compartment supply passage; a compartment exhaust port for each of said compartment exhaust passages formed in an end of the rotor and so disposed and arranged as to periodically overlap the exhaust port, whereby the compartments are periodically connected to pressure and exhaust and the vanes are periodically extended and retracted to roll the rotor around inside the case, the race and bearing surfaces being in constant rolling contact with each other during rolling movement of the rotor within the case.

16. A vibrator according to claim 15 in which the compartment-forming surfaces in the rotor and case are joined to respective adjacent races and bearing surfaces by shoulders which lie normal to the axes of the case and rotor, and in which at least some of the passages periodically open onto their compartments through some of said shoulders, whereby to accomplish a valving action.

17. A fluid-powered vibrator according to claim 1 in which one of the compartment-forming surfaces of each co-acting pair is resilient, whereby the major proportion of the eccentric force exerted on the case by rolling of the rotor within the case is applied at the race.

18. A fluid-powered vibrator according to claim 17 in which the compartment-forming surface on the rotor is resilient.

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