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VIBRATOR

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FIG. 1

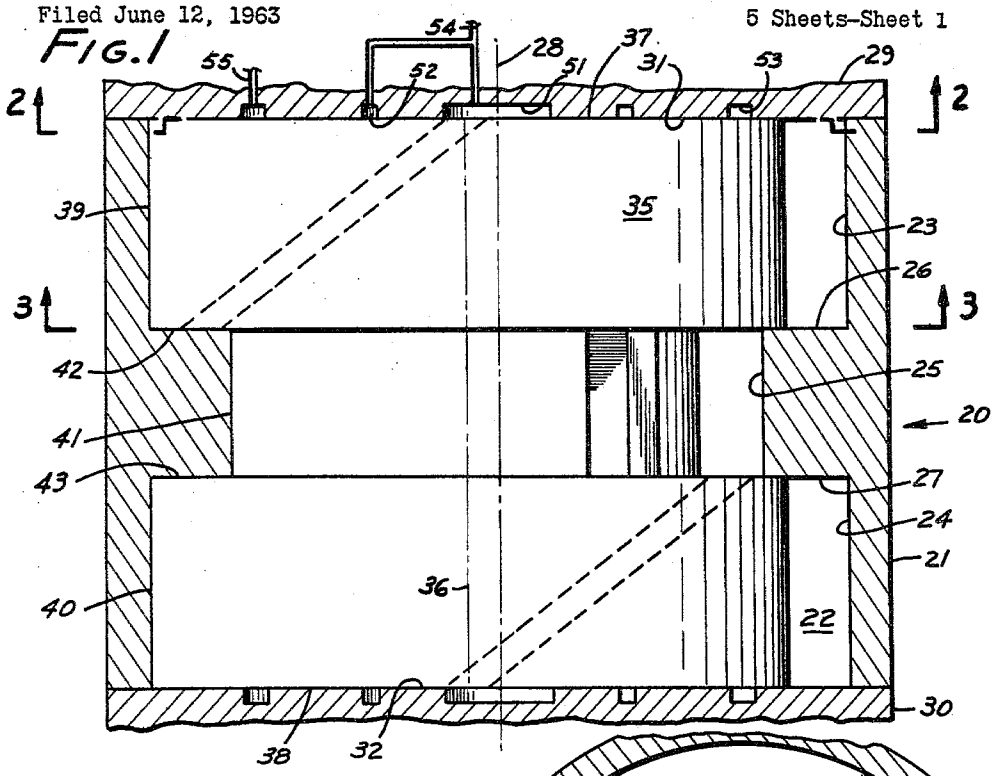


FIG. 2

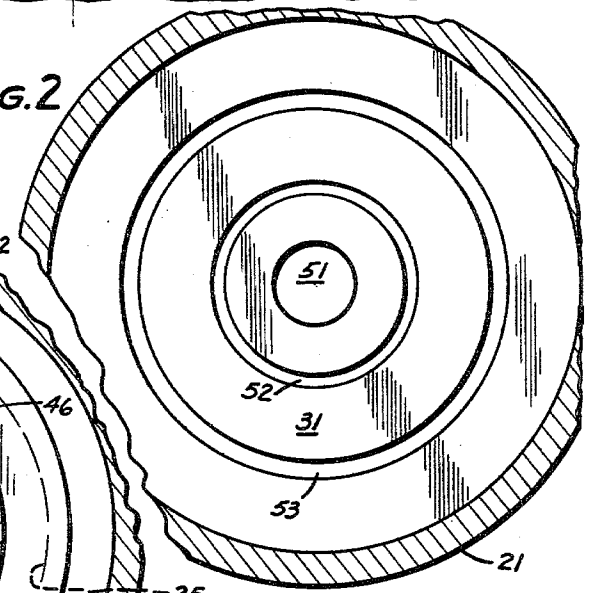
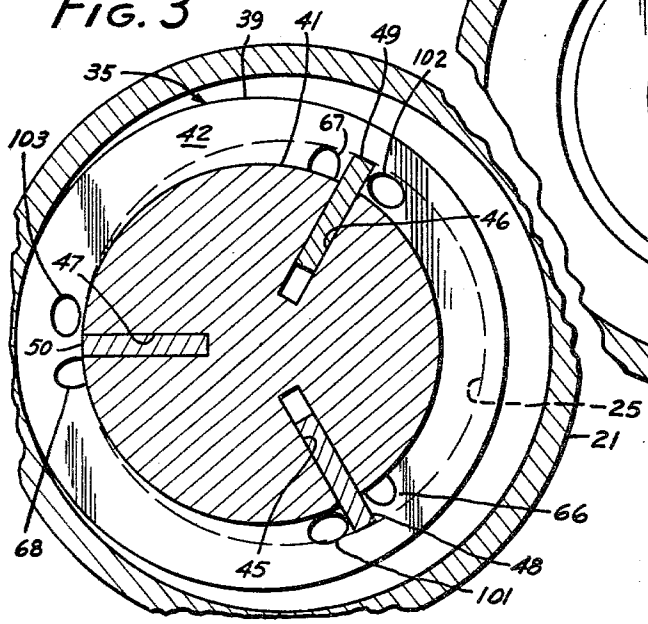


FIG. 3



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FIG. 4

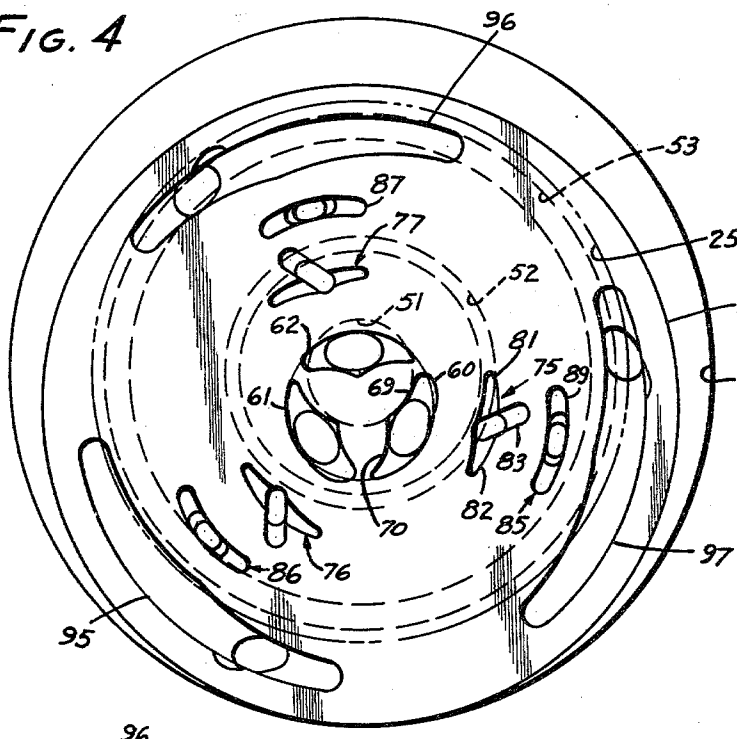
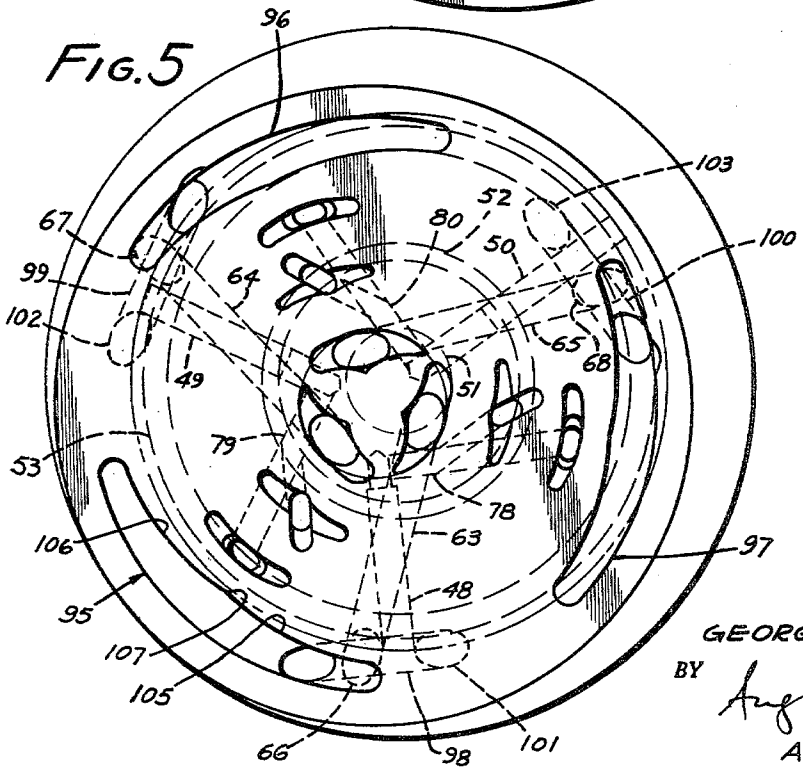


FIG. 5



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FIG. 13

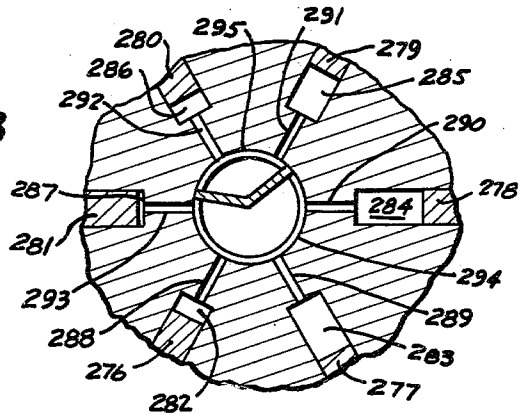
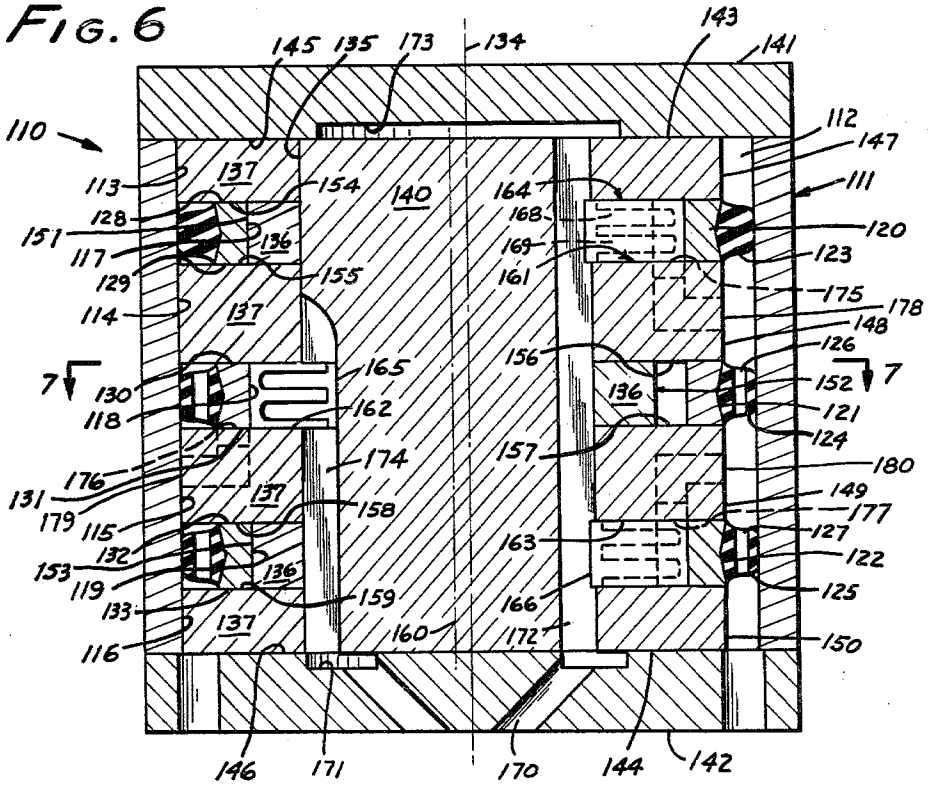


FIG. 6



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FIG. 7

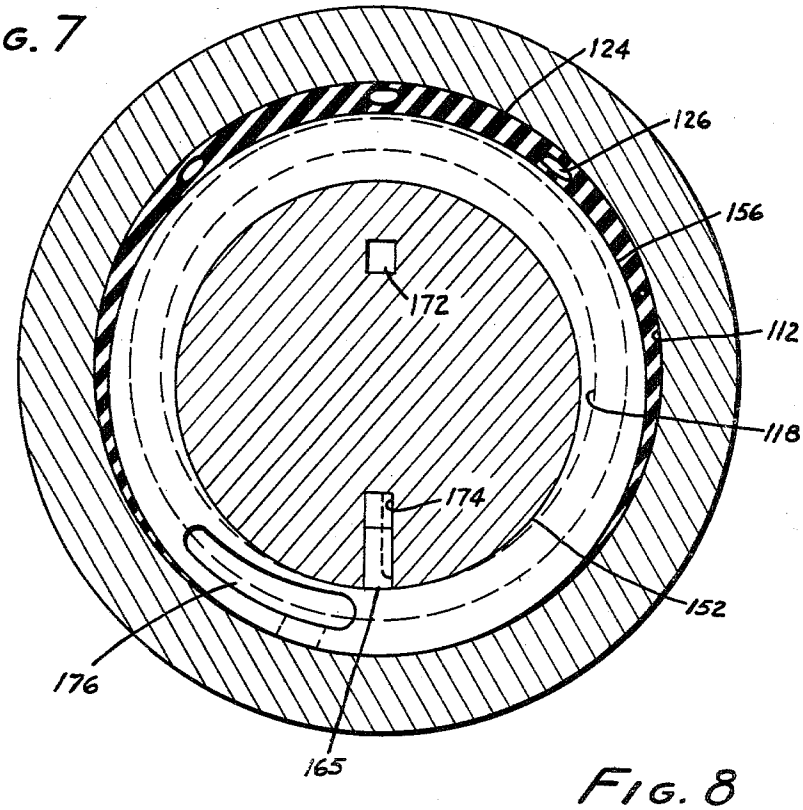


FIG. 8

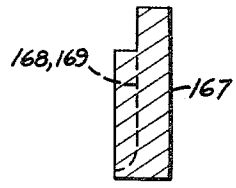


FIG. 9

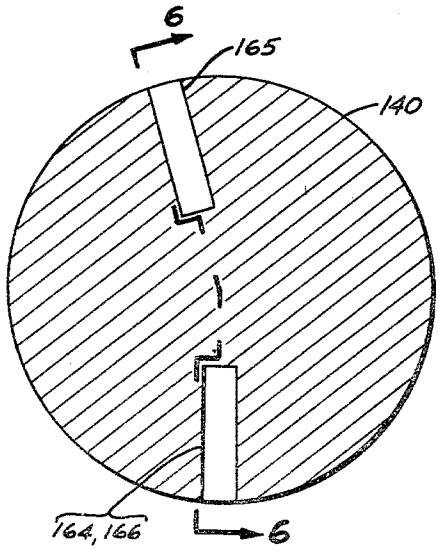
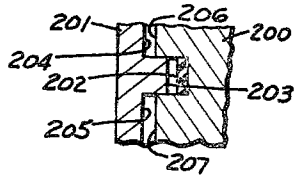


FIG. 10



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FIG. 11

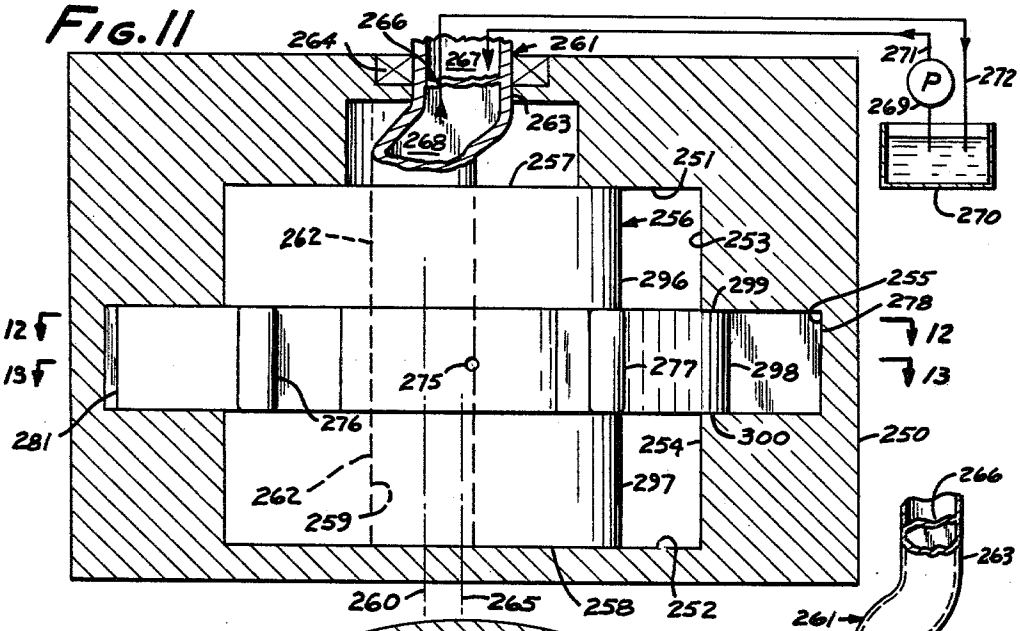
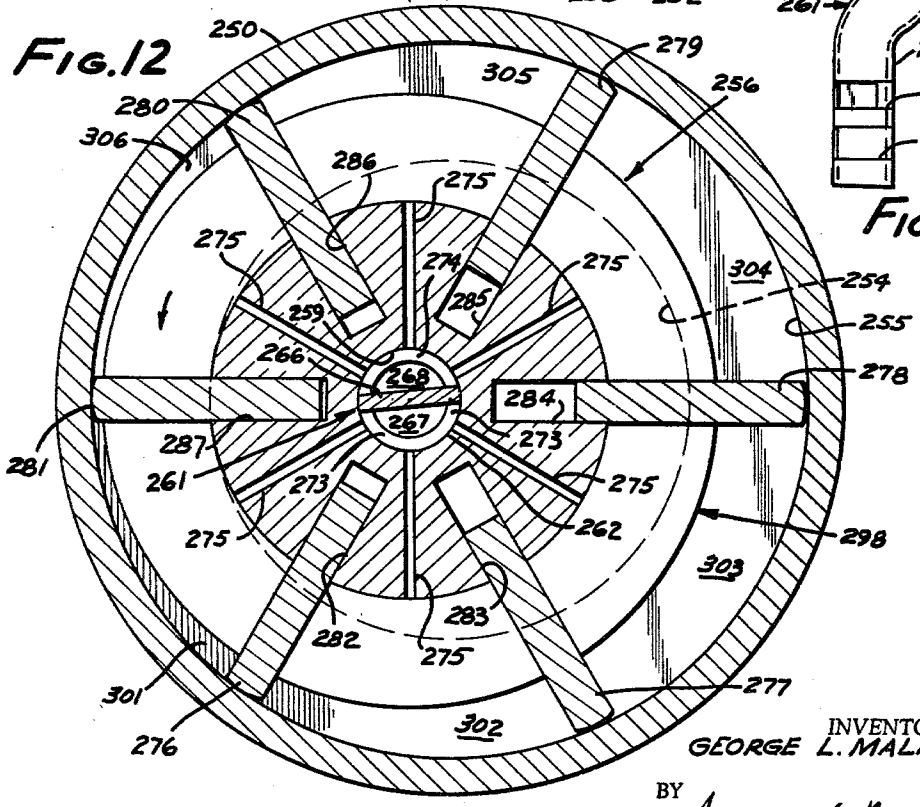


FIG. 12



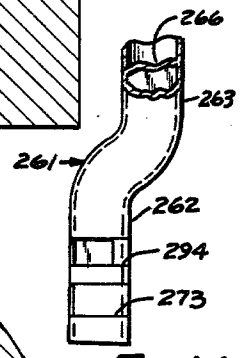


FIG. 14

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United States Patent Office

3,193,256
Patented July 6, 1965

3,193,256

VIBRATOR

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Filed June 12, 1963, Ser. No. 287,408
8 Claims. (Cl. 259—1)

This application is a continuation-in-part of applicant's co-pending patent application, Serial No. 185,479, filed April 5, 1962, entitled "Vibrator With Separate Bearing and Compartment-Forming Surfaces," now Patent Number 3,129,925.

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 the aforesaid 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 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 very substantial volume of fluid has to be taken into the case and expelled from it for each trip of the rotor around the race. This volume is about equal to the area swept by the vanes in their progress. While this volume is not a particularly serious problem when a gas is used for power, the rate is very large when liquids are used and the rotor makes about 12,000 r.p.m. Heretofore it has not been feasible to use liquids under pressure for power, because of this rate.

There is a growing interest in the possibility of using liquids under pressure for powering vibrators. If run at relatively high pressures of several hundred or more p.s.i.g., compared to the 70–100 p.s.i.g. pressures commonly used for air, significant operating advantages can be obtained, but not if comparably 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 throughput 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 vbirator 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 were 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 vibrators 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 to 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 major portion of 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, and the rest in the exhaust line. This constitutes a waste of a substantial portion of the energy of the compressed gas.

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

The provision of separate surfaces for transfer of eccentric rolling forces, and the surfaces where propulsion of the rotor occurs not only saves wear on interrupted surfaces and expands the choice of valving techniques, but also enables improved motor structures to be used. The term "motor" is used in the broad general sense of means for propelling the rotor around the race. It is an object of this invention to utilize improved motor means and a consequence of the separation of function provided by this invention.

A fluid-powered vibrator according to this invention comprises a case having an internal circular race with a diameter and a central axis. 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 circular bearing surface on the rotor is adapted to roll along the race, the bearing surface having a lesser diameter than the race. Motor means is provided for propelling the rotor around inside the race, the motor means and the rotor being rotatively coupled.

According to a preferred but optional feature of the invention, the case includes a circular compartment-forming surface (sometimes called a "reaction surface") with a second diameter, the diameter of the race being called the "first" diameter. The diameter of the bearing surface on the rotor is called the "third" diameter. A circular 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 when the compartment-forming surfaces are to roll on one another as well as the race and bearing surface, and a greater or lesser increment when they are not to roll on each other, depending on whether the recessive compartment-forming surface is in the case or in the

rotor. The bearing surface and the compartment-forming surface on the rotor are concentric.

In the preferred embodiment, 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 is thereby 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. The compartment-forming surfaces and vanes form the "motor means" in this invention.

According to another 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 feature of the invention, the compartment-forming surfaces carried by the case are resilient or yieldable. The vanes operate against this surface, which cushions some of the hard blow which is given to that surface when a vane is suddenly put under pressure. Furthermore, by providing a resilient region for this part of the vibrator, the major portions of the rolling kinetic energy are transmitted to the case through the unbroken races, which are not interrupted by vane slots. This increases the life of the races, because there are no discontinuities to wear at a faster rate than other regions.

According to still another optional feature of the invention, the increment between the third and fourth diameters differs from that between the first and second diameters so that the compartment-forming surfaces do not roll on each other, thereby saving wear thereon, and so that the compartments are defined in part by two vanes.

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 an 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;

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

FIG. 11 is a side elevation, partly in cutaway cross-section, showing the presently preferred embodiment of the invention;

FIG. 12 is a cross-section taken at line 12—12 of FIG. 11;

FIG. 13 is a fragmentary cross-section taken at line 13—13 of FIG. 11; and

FIG. 14 is a side elevation of a distributor used in the vibrator of FIGS. 11 and 12.

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 inch, and is adjusted by tightening up on the end plates until the desired operation of the rotor under power takes place.

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 coextensive 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 in the compartments between surface 25 and 41, and by fluid pressure on the vanes which provides a force between the rotor and case by pressing the vanes against surface 25. The valving and passages for creating these forces and pressures in appropriate regions will now 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 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 nearly equal axial pressure loads on the rotor as possible, thereby minimiz-

ing 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 concentrically with port 51. It has a large diameter than port 51, 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 conduit 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 port in both end plates to conuits 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 is to be again understood that the mirror immage construction exists in the rotor at the lower end thereof in the preferred embodiment of the invention so that supply and exhaust are provided for both ends of the rotor, thereby providing for maximum fluid-flow passages and for a fluid-balanced 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 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 and 97 are spaced 120° apart in rotor end surface 37. They connect through compartment exhaust passages 98, 99, 100, respectively, to the compartments immediately counterclockwise 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 edges 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 bound the sides of rings 120–122. These shoulders lie normal to central axis 134 of the case. The races and the case's compartment-forming surfaces are coaxial around axis 134.

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.

While it is possible to machine various grooves and passages into an initially integral body of metal, an easier manufacturing technique is to form the rotor from a core 135, three compartment rings 136 and four race rings 137, all of which may be initially individual machined or otherwise formed to a desired configuration, and thereafter joined together by brazing or otherwise to form the integral rotor. The lines of contiguity between core 135 and rings 136 and 137 are therefore joinder lines, which would not appear had the rotor been "hogged" out of a single piece of metal.

The rotor includes four bearing surfaces 147, 148, 149, 150. Three cylindrical compartment-forming surfaces 151, 152, 153 are formed on the insides of the compart-

ment rings between adjacent pairs of the bearing surfaces. Flat planar shoulders 154, 155, 156, 157, 158 and 159 are formed on the race rings radially outward from the compartment rings. These shoulders lie normal to the central axis 160 of the rotor, and form boundaries for the bearing surfaces and for the compartment-forming surfaces on the rotor. Surfaces 147–150, 151–153 and shoulders 154–159 are coaxial around central axis 160 of the rotor.

The races, bearing surfaces, and compartment-forming surfaces have the same relationship as to diameters as in the embodiment of FIG. 1, differing by increments between first and second, and third and fourth diameters, in the same 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 provide 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 156, 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 resultant force 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. 9, in which the positions of vanes 164, 165 and 166 are noted by lines.

FIGS. 11–14 illustrate the presently preferred embodiment of vibrator according to the invention. A case 250 includes an internal cavity partly bounded by a pair of end faces 251, 252, a pair of races 253, 254 having a first diameter, and a cylinder-forming surface 255 between them. Surface 255 has a second diameter which differs from the first by an increment.

A rotor 256 has a pair of end faces 257, 258, at least part of which move slidably relative to the cavity and faces. The rotor has an internal distributor opening 259 on its axis 260.

A distributor 261 is an offset member with two parallel arms 262 and 263. Arm 262 fits in opening 259 and is coaxial with the rotor axis. Arm 263 is mounted to the case by bearing 264 and rotates around case axis 265. A baffle 266 extends the length of the distributor, and divides its interior into a pressure supply passage 267 and an exhaust passage 268. A pump 269 supplies the pressure passage from reservoir 270 through line 271, and line 272 returns exhaust fluid from passage 268 to the reservoir.

Compartment pressure supply port 273 and compartment exhaust port 274 open through the side of the distributor at a first elevation in the rotor level with compartment supply passages 275 (FIG. 12).

Six vanes 276–281 are slidably fitted in vane recesses 282–287, respectively. They project beyond the outer periphery of the rotor. Vane supply passages 288–293 (FIG. 13) open through the side of the distributor at second elevation (different from the first elevation of the compartment supply passages). Vane supply port 294 and vane exhaust port 295 open through the distributor in the rotor level with the vane supply passages. It will be observed that the vane supply port has a greater peripheral length than the vane exhaust port. This is because a firm pressure of vane against the opposite compartment-forming surface is desirable at all times that an adjacent compartment is pressurized in order to prevent blow by to an adjacent compartment which is at exhaust pressure. Apart from the need to keep pressure on both vanes bounding a compartment under pressure, the timing of the exhaust connections to the vanes is not critical. The vibrator will operate with the vanes always connected to pressure, but this would mean that one part of the vibrator would be working against, instead of with, some other part. Therefore, ports 294 and 295 are set so that each vane recess will be placed on exhaust connection except when a compartment it bounds is under pressure.

The compartment supply and exhaust ports are so disposed and arranged that a pressure connection is made to the compartments which are growing in volume, and an exhaust connection is made to the compartments which are descreasing in volume. The changes from decrease to increase and vice versa occur when the tangent between the rotor and the case in midway between the respective bounding vanes.

The outer periphery includes two bearing surfaces 296, 297 having a third diameter, and a compartment-forming surface 298 having a fourth diameter. In this embodiment, the rotor's compartment-forming surface is bounded by two external shoulders 299, 300, which make a sliding seal with equally-spaced shoulders on the case.

The fourth diameter is larger than the third. An important feature of this embodiment is that the increment between the third and fourth diameter is different (less here) than the increment between the first and second diameters. Compartments 301–306 are therefore formed between adjacent vanes, segments of two compartment-forming surfaces, and bounding race and rotor shoulders. The compartment-forming shoulders do not roll on each other, and all wear at the edges of vane recesses and the like is eliminated. Furthermore, because the tangent line between the rotor and race is not used as a compartment boundary, even greater flexibility of timing the pressure and exhaust cycle is attainable. The vanes extend axially for the full length of the compartment-forming surfaces.

It will be noted that the distributor will prevent the rotor from moving to a central position where the axes

of the rotor and case would be coincident. Therefore, the rotor and race will reliably start, and will never be in an inoperative relative position.

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 rgistration 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 counter-clockwise 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 52. 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 85 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 compartment 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 fluid pressure in the recesses, through 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 emodiment 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 arrangemennt 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.

The operation of the device shown in FIGS. 11–13 will now be described. At any position of the rotor and the distributor, some compartment supply passages and vane supply passages will be on pressure and exhaust connections because of their registration with the ports in the distributor. Compartments and vane recesses under pressure will receive fluid (either liquid or gas). As can be seen from FIG. 12, this can be over as much as one full half of the rotor periphery. The remainder is on exhaust. The action is sequential. The pressure is on in a vane recess when the vane bounds a compartment under pressure.

In FIG. 12, compartments **301**, **302** and **303** are under pressure, and compartments **304**, **305** and **306** are under exhaust. About the time the tangent line reaches the midpoint in compartment **306**, this compartment will go onto pressure, and compartment **303** onto exhaust. In the same figure, vanes **276**, **277**, **278** and **281** are under pressure in their recesses. Vanes **279** and **280** are under exhaust. When compartment **306** goes onto pressure, so will vane **280**. Vane **278** will go onto exhaust when compartment **303** does. Therefore, on the average, three compartments and four vanes will be on pressure, and three compartments and two vanes will be on exhaust. Slight overlaps from this condition, and different angles of pressure-on and pressure-off conditions relative to the tangent may occur or be designed into the rotor, but these would not affect the general scheme of rotor operation.

In FIG. 12, the tangent line between rotor and case moves clockwise around the case, and the distributor turns clockwise. The rotor rotates counter-clockwise around its own axis.

The term "fluid" as used herein encompasses both liquids and gases.

The term "free rotor vibrator" as used herein is intended to encompass that class of vibrators wherein the rotor is not rigidly mounted to a case in such a manner that the eccentric load is transferred to the case by bearings. The load transfer herein is substantially totally through the race. While in some embodiments a rotary distributor will serve to prevent the rotor from moving to some central positions, still it has no part in the force transfer. In fact, clearances may be provided to avoid exerting side forces on the distributor, or the distributor may even be somewhat flexible. Thus, "free rotor" does not necessarily mean total disconnection from the case (although it may) but does mean that the basic force transmission is to the case from rolling contact with the rotor.

The term "motor means" as used herein means any type of fluid motor wherein one element of the motor is rotatably coupled to the rotor. In the embodiments, shown, the rotor is a single, unitary body, the motor means comprising the compartment-forming surfaces (sometimes called "reaction surfaces"), and the vanes. Should only vanes be used for propulsion, then only the reaction surface on the case reacts in the motor operation. Should the compartments be pressurized, then both reaction surfaces are used. In the preferred embodiment, where the bearing surface and rotor portion of the motor form a unitary structure, these are clearly "close-linked." However, the motor means need only provide some kind of eccentric drive, even a crankshaft-type drive, to which that part of the rotor carrying the bearing surface is journaled, and analogous results within the scope of this invention are achieved.

Any number of motor means may be provided, as may any number of races and bearing surfaces.

In separating motor and load transfer functions, this invention provides great flexibility in vibrator design, and significantly decreases wear, thereby increasing the life of the vibrator. Because "down time" is so very expensive on major construction projects, significant stand-by units are ordinarily provided. By increasing the length of the service intervals, very considerable savings can be made.

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 side 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 which 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 have having a fourth diameter which differs from the third diameter by another increment, the bearing surface and the compartment-forming surface on the rotor being concentric; a plurality of vanes carried by the rotor, which vanes are reciprocable within, extensible beyond, and axially coextensive with, the compartment-forming surface on the rotor, and thereby being adapted to form a compartment between a pair of adjacent vanes and the two compartment-forming surface; and fluid supply and exhaust means for causing rolling movement of the rotor within the case of 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, the fluid supply and exhaust means including a distributor which comprises an offset element journaled to the case and to the rotor, at the axes of each, and being thereby adapted to turn as a crank when the rotor rolls in the case, the distributor having supply and exhaust passages adapted to be connected to a supply of pressurized fluid and to a collector of exhaust fluid, respectively, and also having supply and exhaust ports peripherally spaced apart within the rotor, and in which the rotor includes a compartment supply passage for each segment of rotor compartment-forming surface between adjacent vanes, the supply and exhaust ports thereby being adapted sequentially to be connected to the compartments.

2. A fluid-powered vibrator according to claim 1 in which vane supply passages are formed in the rotor, one for each vane to provide pressure and exhaust fluid connections to the inner ends thereof, said vane supply pas-

sages being so disposed and arranged as sequentially to register with said distributor supply and exhaust ports.

3. A fluid-powered vibrator according to claim 1 in which the offset element is so jointed to the rotor and case as to prevent the rotor from reaching a central position in the case.

4. A free rotor vibrator comprising: a case with an axis and having an inner circular race; a rotor with an axis and having an exterior circular bearing surface of lesser diameter than the race and adapted to roll around the race in contact and eccentric-load transfer relationship therewith; fluid motor means comprising: a circular reaction surface in said case an coaxial with the case axis, and axially spaced from the race, a support surface on the rotor axially aligned with the reaction surface and being so proportioned and arranged as to be held out of contact with the said reaction surface by virtue of the contact between the bearing surface and the race, and extensible means carried by the rotor adapted to be extended from the support surface of the rotor to press against the reaction surface, thereby to provide propulsive force for propelling the rotor around the race; and fluid-valving means for applying fluid under pressure to extend said extensible means.

5. A free rotor vibrator according to claim 4 in which extensible means comprises a vane for forming compartments between said reaction surfaces, the valving means supplying fluid under pressure sequentially to said compartments to aid in propelling the rotor in the case.

6. A free rotor vibrator according to claim 5 in which a plurality of vanes is provided to create more than two compartments.

7. 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 case inside of the case having a second diameter which differs by 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 an increment, the increments and diameters being such that there is not restraint to prevent the bearing surface from making full rolling contact with the race, 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 two the compartment-forming surfaces; and fluid supply and exhaust means for causing rolling movement of the rotor within the case by periodically placing commpartments under greater and lesser pressures, the race and bearing said surface its constant rolling contact with each other during said rolling movement.

8. A fluid-powered vibrator according to claim 7 in which a first and a second flat annular shoulder lie normal to the axes of the rotor and race, and respectively inter connect 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.

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CHARLES A. WILLMUTH, *Primary Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,193,256 July 6, 1965

George L. Malan

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 5, line 8, for "large" read -- larger --; lines 20 and 21, for "conuits" read -- conduits --; line 24, for "immage read -- image --; column 7, line 22, for "provide" read -- provided --; column 9, line 19, for "rgistration" read -- registration --; column 12, line 5, after "embodiments" strike out the comma; line 41, for "which" read -- within --; line 45, strike out "have"; line 53, for "surface" read -- surfaces --; same column 12, line 55, for "of" read -- by --; column 13, line 13, for "an" read -- and --; column 14, line 6, for "not" read -- no --; line 13, for "two the" read -- the two --; line 17, for "commpartments" read -- compartments --; line 18, for "bearing said surface its constant" read -- bearing surfaces being in constant --; lines 23 and 24, for "inter connect" read -- interconnect --.

Signed and sealed this 22nd day of February 1966.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents