# United States Patent [19]

**Hause et al.**

[11] **3,777,622**

[45] **Dec. 11, 1973**


[54] **PUMPS AND MOTORS**


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[73] Assignee: **General Motors Corporation**, Detroit, Mich.



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[52] **U.S. Cl.** .................... **91/479**, 91/494, 417/273, 91/497

[51] **Int. Cl.** .................... **F01b 13/06**

[58] **Field of Search** .................... 91/479, 490, 493, 91/496, 497; 417/269, 467



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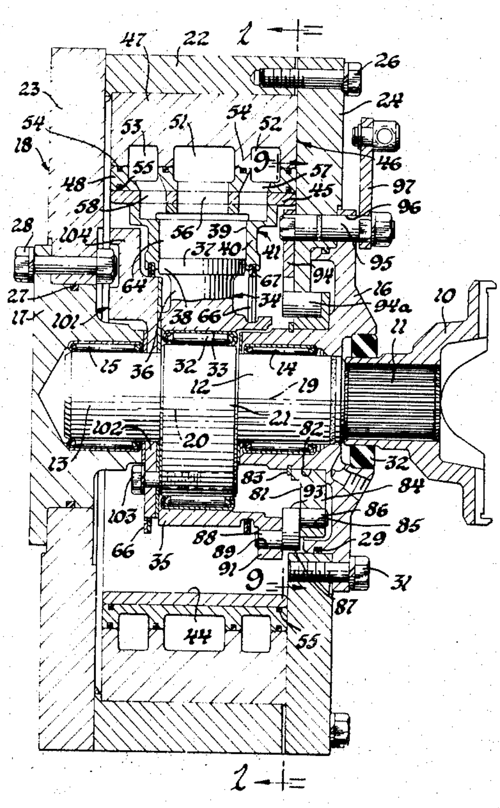
*Attorney*—W. E. Finken et al.


[57] **ABSTRACT**


A fluid pressure orbiting piston oscillating cylinder machine for use as a fluid pump or motor having a drive or driven power shaft rotatably mounted in a housing and having an eccentric and crank mechanism supporting a spider for orbiting movement. The spider has a plurality of radial arms each having fixed on the radial outer end a spherical piston fitting in a cylindrical cylinder. Each piston is coaxially aligned with the radius of its spider arm. The cylinder has a transverse cylindrical base in bearing engagement with a fixed internal cylindrical bearing surface coaxial with the shaft. A manifold in the housing is connected by ports in the internal cylindrical bearing which cooperate with ports in the cylinder base so that during rotation of the power shaft the pistons orbit in a circular path and the cylinders rotatably oscillate relative to the fixed internal cylindrical bearing to control porting for pump and motor operation. Capacity is controlled by a control ring adjustably rotated about the power shaft axis and connected by cranks to the spider to control the angular position of cylinder oscillating movement relative to the position of the ports in the cylindrical bearing to control the porting to vary capacity between zero and full capacity. In a fluid pump or motor, inlet and outlet manifolds and ports provide feed to and discharge from the cylinders. In a compressor there is a feed manifold and discharge through a check valve through the interior of the housing to the outlet.


**14 Claims, 13 Drawing Figures**



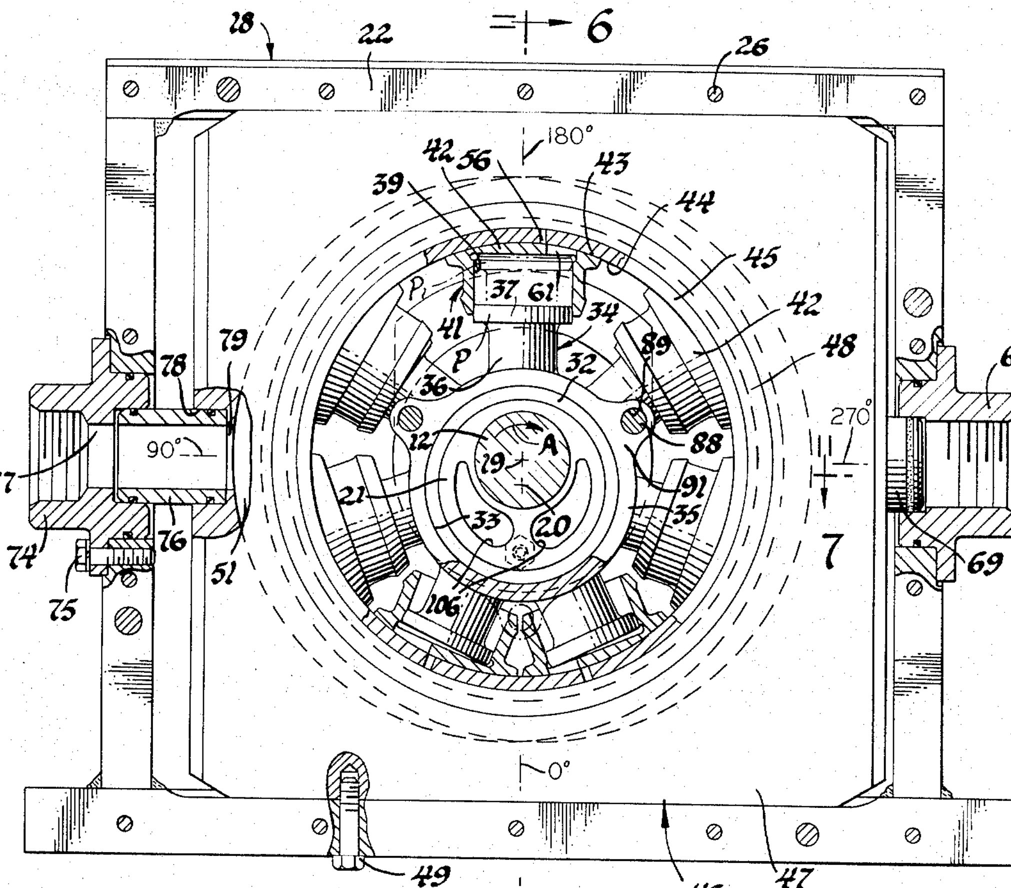



Fig.1

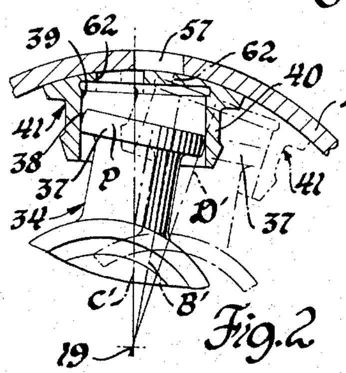



Fig.2

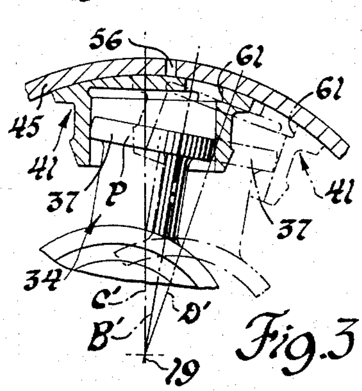



Fig.3

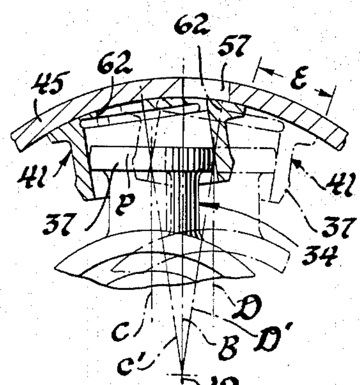



Fig.4

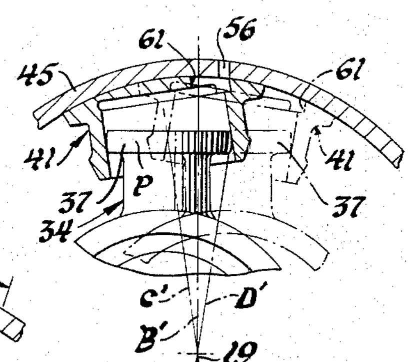



Fig.5

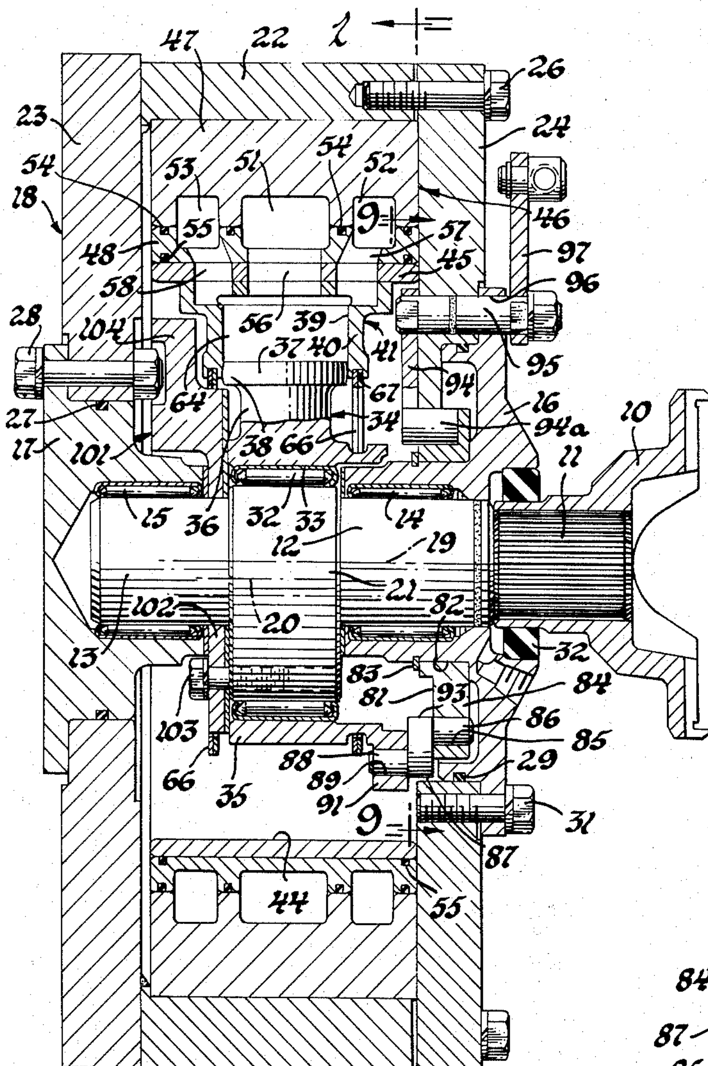



Fig.6

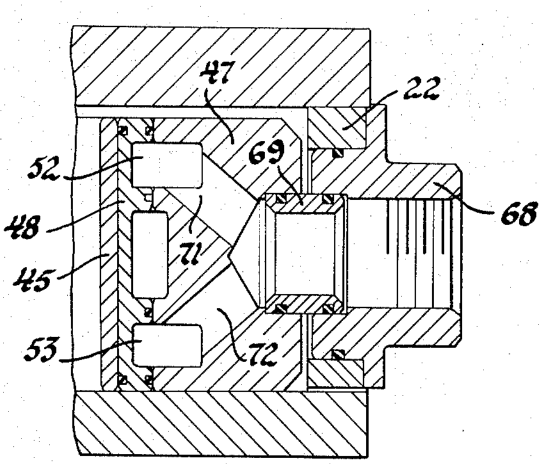



Fig.7

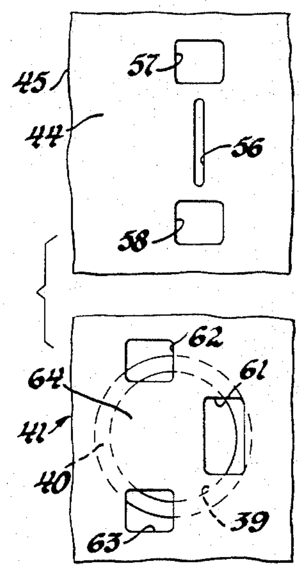



Fig.8

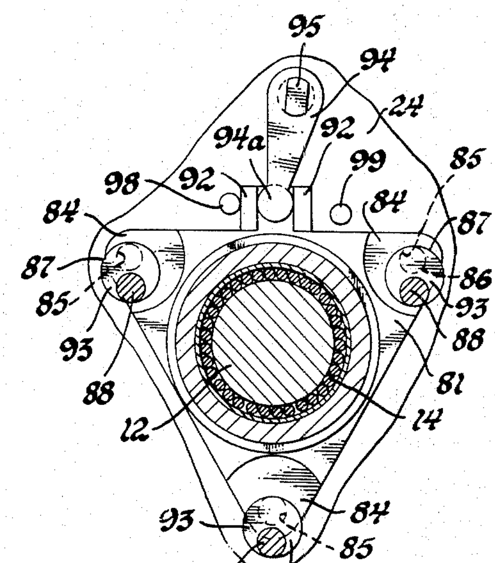



Fig.9

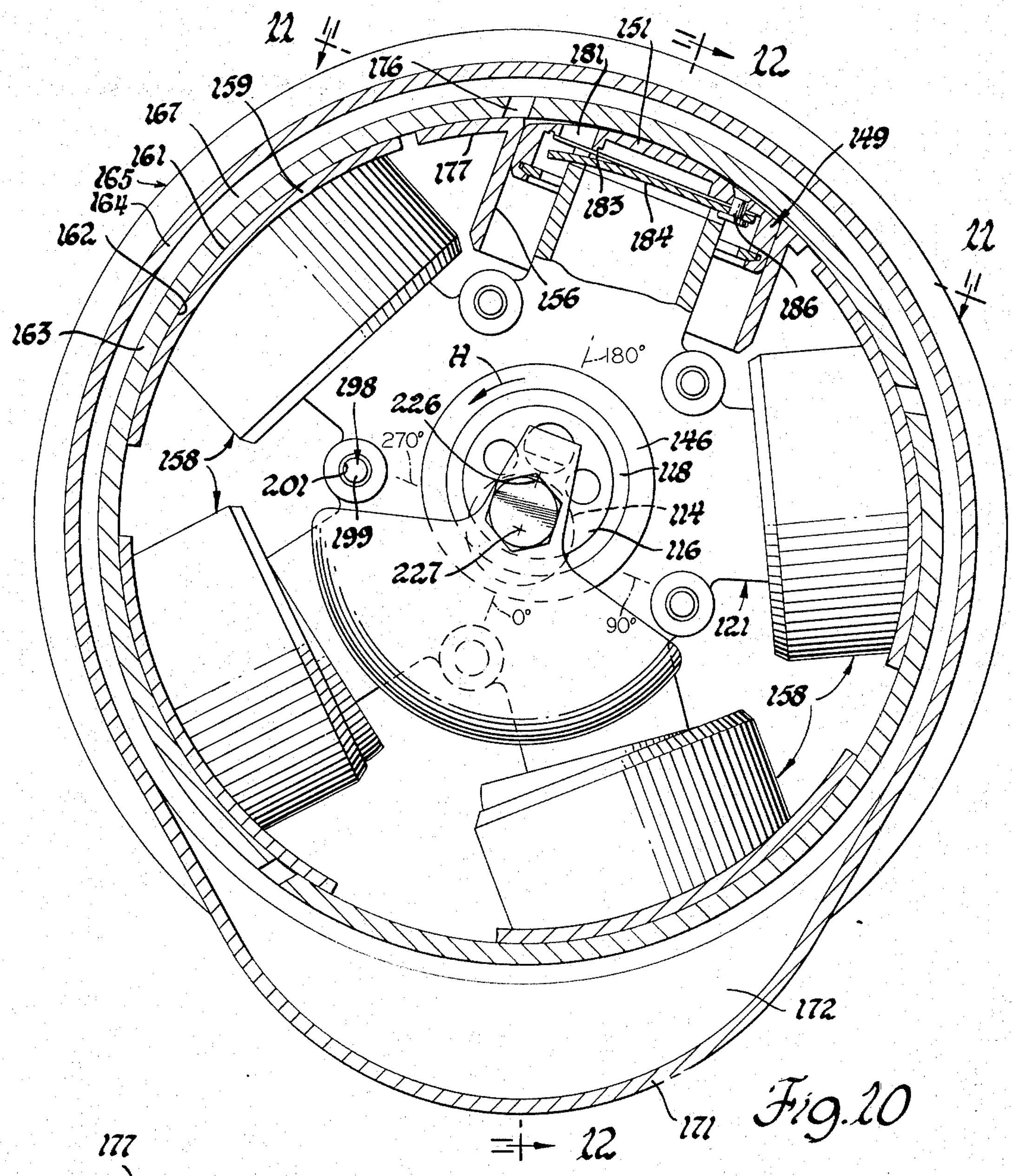

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Fig.10

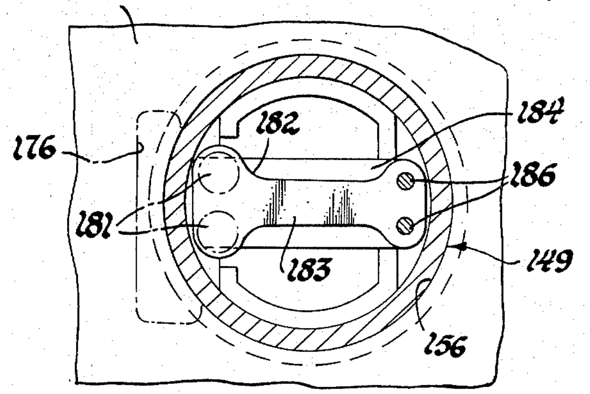
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Fig.11

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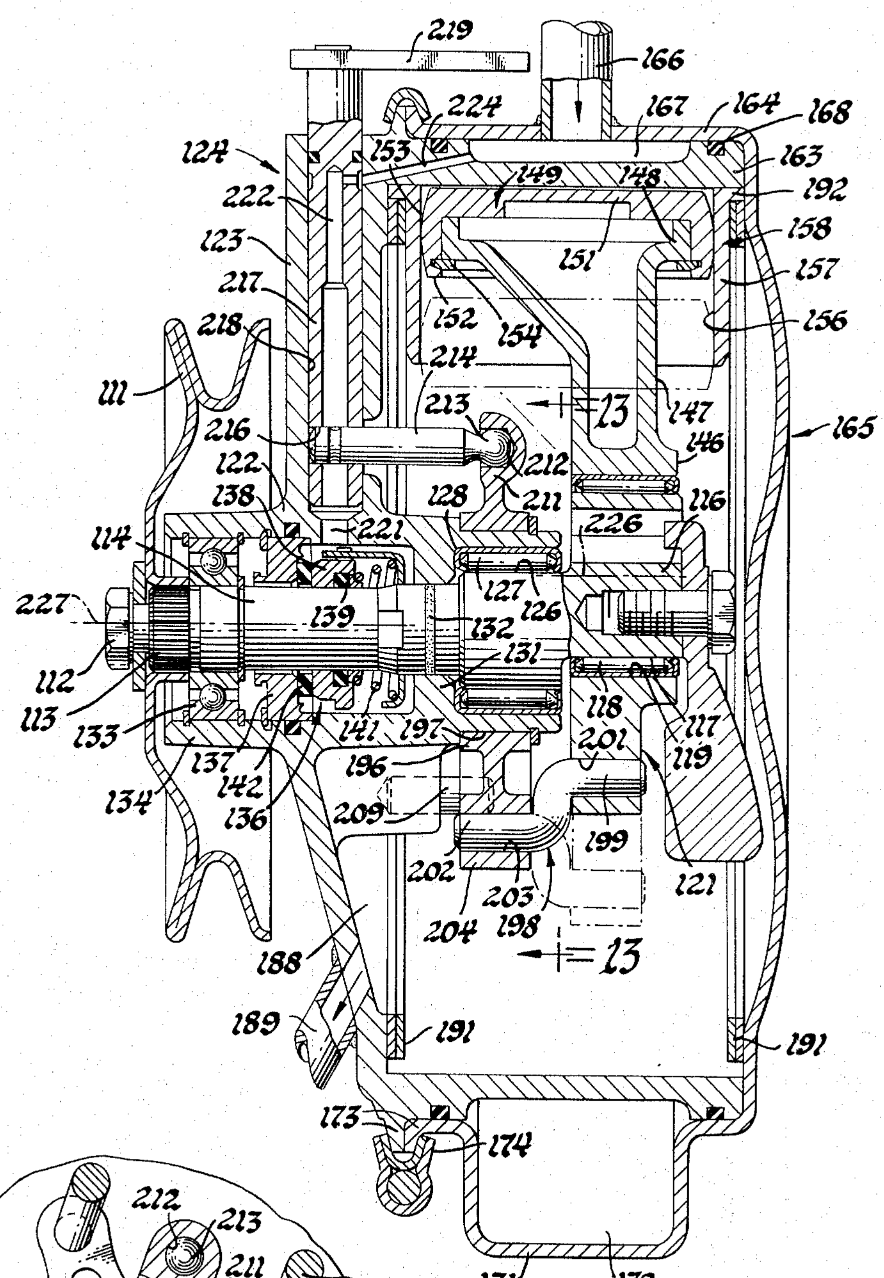


Fig.12

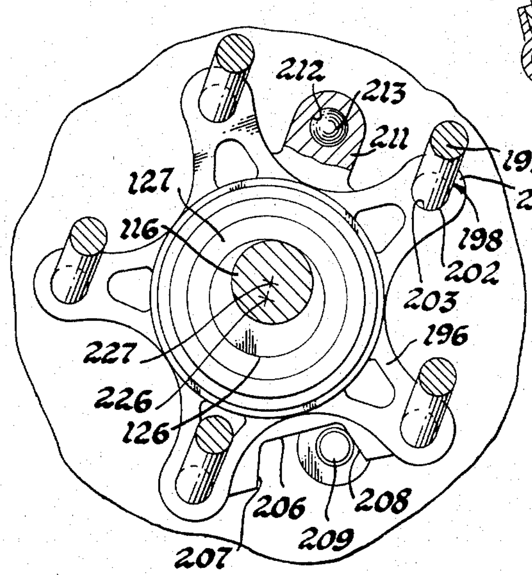


Fig.13

## PUMPS AND MOTORS

This invention relates to fluid pressure machines and particularly to a variable capacity orbiting piston and oscillating port controlling cylinder type of fluid pressure machine.

The fluid pressure machine, a pump or motor, according to this invention, has a power shaft rotatably mounted in a housing and having an eccentric. A spider is mounted on the eccentric for eccentric bodily movement and oscillatory rotation and has a plurality of radial arms, each having fixed on the radial outer end, a sperical piston. The spherical piston fits in a cylindrical cylinder having a cylindrical bearing base portion supported on an internal cylindrical bearing or bearing ring fixed to the housing. The spider movement is controlled by a plurality of cranks connected to a control ring fixed for each degree of capacity. Thus, during rotation of the power shaft, the spider will move in an orbit around the machine axis and the pistons will move in an orbit controlled by the crank mechanism connected to the control ring which is rotatably adjustable for varying the capacity of the machine. The orbiting movement of the pistons causes the pistons to reciprocate in the cylinders and the cylinders to rotatably oscillate relative to the fixed internal cylindrical bearing and control the porting in the internal cylindrical bearing and cylinder base for controlling the transfer of fluid through the machine and thus machine capacity. In this type of construction the high speed power shaft is supported directly in the housing by conventional small bearings and the high speed eccentric cam has a small diameter, since a large diameter for porting is not required. The cylinders, or cups, merely have a small oscillatory movement relative to the internal cylindrical bearing and do not rotate at high speed and thus the high centrifugal load normally found in rotary machines of this character is eliminated. The reciprocating movement of the piston in the cylinder causes the cylinder to move in an oscillatory path on the fixed bearing ring and this movement controls the portion for the pump or motor operation.

These and other features of the invention will be more apparent from the following description and drawings.

FIG. **1** is an elevation view of the fluid pressure machine functioning as a pump with parts in section to show details.

FIG. **2** is a partial view of a piston, cylinder and bearing ring to show the full range of movement of the inlet or suction porting for unloaded or zero capacity operation.

FIG. **3** is a partial view of a piston, cylinder and bearing ring to show the full range of movement of the outlet or pressure ports for unloaded or zero capacity operation.

FIG. **4** is a partial view of a piston, a cylinder and the internal cylindrical bearing ring showing the full range of movement of the inlet or suction ports for full stroke or capacity operation.

FIG. **5** is a partial view of a piston, a cylinder and the internal bearing ring showing the full range of movement of the outlet or pressure ports for full stroke or capacity operation.

FIG. **6** is a sectional view of FIG. **1** on the line **6—6.**

FIG. **7** is a partial sectional view of FIG. **1** on the line **7—7** showing the manifold.



FIG. **8** is a developed view showing the ports on the cylinder base and bearing ring.

FIG. **9** is a partial section of FIG. **6** on the line **9—9** showing the displacement control linkage.

FIG. **10** is an end sectional view with parts in section to show details of a modified fluid pressure machine of the compressor type.

FIG. **11** is a partial section of FIG. **10** on the line **11—11** showing the ports and valve.

FIG. **12** is a sectional view of FIG. **10** on the line **12—12.**

FIG. **13** is a partial sectional view of FIG. **12** on the line **13—13** showing the displacement control linkage.

The fluid pressure orbiting piston oscillating cylinder machine illustrated in FIGS. **1** to **9** is especially suited for use as a hydrostatic pump or motor. Referring particularly to FIG. **6**, a power connector **10** is suitably splined to a power shaft **11**, which in a pump is the input or drive shaft and in a motor is the output or driven shaft, has a pair of spaced coaxial bearing portions **12** and **13** rotatably supported respectively in needle bearings **14** and **15** supported in the bearing support portions **16** and **17** of the housing **18** for rotation about shaft or machine axis **19.** The shaft **11** between the bearing portions **12** and **13** has on eccentric axis **20,** a small cylindrical eccentric portion **21** located centrally between the bearings. The housing **18** has an outer peripheral shell **22** having side plate **23** permanently secured, as by welding, to one side of the shell **22** and a removable cover plate **24** secured by suitable fastening screws **26** to the other side of the shell **22.** The bearing support member **17** fits in the central aperture of side plate **23** and is sealed thereto by seal **27** and secured therein by suitable bolts **28.** The bearing support member **16** similarly fits within the central aperture in housing cover plate **24** and is sealed thereto by seal **29** and secured by screw fasteners **31.** It will be noted that the bearing support **17** closes the housing at the free end of shaft **11** and that the connector end of shaft **11** is suitably sealed by a seal **32** between the bearing support portion **16** and the connector member **10** of shaft **11** so the housing **18** completely encloses the pumping mechanism.

The central eccentric **21** provides a cylindrical bearing surface, centered on eccentric axis **20,** eccentric to the axis **19** of the shaft **11** and the machine axis for the needle bearing **32** which fits in a central cylindrical aperture **33** of the spider **34** which has a central annular portion **35** and a plurality of radially extending arms **36** each terminating at their outer radial ends in a piston portion **37** coaxial with the radial axis of the arms and having spherical portion **38** contacting the inner cylindrical wall **39** of the cylinder structure **41.**

As shown best in FIG. **1**, there are **7** pistons, each with a cylinder, but it will be appreciated that the number of pistons and cylinders may be varied to suit design needs. The pistons are equally annularly spaced and located the same radial distance from the center or axis of the spider which, when mounted on the eccentric, is also the center or axis **20** of the eccentric displaced an eccentric distance from the shaft axis.

Each cylinder **41** has a cylindrical portion **40** fitting over the piston and a base portion **42** which has a cylindrical bearing surface **43** perpendicularly transverse to the cylinder axis and fitting the internal bearing surface **44** of bearing ring **45** which is supported on, and secured by, the manifold structure **46**, secured within the housing **18**.

The manifold structure **46**, as best shown in FIGS. **6** and **7**, has an outer manifold member **47** and an inner annular member **48**, each having a matching central long annular groove to provide the large high pressure or outlet annular passage **51** and on each side thereof two narrow annular grooves to provide two annular low pressure suction or inlet passages **52** and **53**. The outer manifold member **47** is fixed to the housing by suitable fasteners, i.e., screws **49**. The bearing ring **45** is fixed to the inner manifold member **48** which is fixed to the outer manifold member **47** by suitable fasteners. The parting line between the outer manifold member **47** and the inner manifold portion **48** has suitable annular seals **54** on each side of the annular manifold passages to prevent leakage. There are similar seals **55** between the inner manifold member **48** and the bearing ring **45**. At each cylinder station the annular outlet manifold passage **51** is connected by a port **56** extending through the manifold portion **48** and the annular bearing ring **45**. The annular inlet manifold passages **52** and **53** are respectively connected by ports **57** and **58** extending through the manifold portion **48** and the annular bearing ring **45**. These ports are shown in the developed view, FIG. **8** of the internal surface of bearing ring **45**.

The cylinder **41** has in the cylindrical surface **43** of the base portion **42** an outlet port **61** and inlet ports **62** and **63** all communicating with the pumping chamber **64** within the cylinder and sealed by the piston. The pistons **41** are held in the position shown in contact with the annular bearing ring **45** by fluid pressure in the pumping chamber **64** and in the absence of such pressure by annular spring rings **66**, one on each side of the spider, and each engaging in a slot **67** in each inner lip of all the cylinders **41**.

The inlet port fitting **68**, FIG. **7**, is suitably secured and sealed to the shell **22** of the housing and connected by a transfer bushing **69** to the outer manifold member **47** and sealed to both the bushing **68** and manifold **47** and connected by passages **71**, **72** to the annular inlet manifold passages **52** and **53**, as shown in FIG. **7**. The outlet port fitting **74**, as shown in FIG. **1** is secured and sealed to the housing by suitable fasteners **75** and a seal. The transfer bushing **76**, fitting within the passages **77** in the bushing and passage **78** in the outer manifold member **47**, is connected by a suitable passage **79** to the outlet manifold annular passage **51**.

The orbiting and displacement control mechanism consists of an annular control ring **81** rotatably mounted concentric with shaft **11** axis **19** on a cylindrical bearing surface **82** on the bearing support member **16** and is retained in axial position by a shoulder and snap ring **83**. The control ring **81** has a triangular external shape to provide three ears **84**, each having an aperture **85** to receive a pin **86** extending from one side of the central portion **93** of crank member **87** which also has an oppositely extending pin **88** fitting into an aperture **89** in an ear **91** formed on the spider **34**. The central portion **93** of the cranks **87** fits between the control ring **81** and the ears **91** to position it axially. These cranks **87** have the same eccentric distance as the main eccentric distance between shaft axis **19** and eccentric axis **20**. The control ring **81**, as shown in FIGS. **6** and **9**, has a pair of axially extending ears **92** with the ball end **94a** of control lever **94** therebetween. The control lever **94** is suitably keyed to the control shaft **95** extending through a seal in aperture **96** in the housing and connected to a suitable control lever **97**. When the control lever is moved to control capacity, the lever rotates the control ring **81** within the limits defined by the pins **98** and **99** fixed in the housing portion **24** and engaging ears **92** to limit movement.

The eccentric flywheel **101** has a ring portion **102** fitting on the bearing portion **13** and is secured by a suitable screw **103** to the side of the eccentric portion **21** and an eccentric weight portion **104** to balance the eccentric and the spider on the main shaft and about the main shaft axis. The eccentric out of balance weight is reduced by apertures **106**.

The operation of this fluid machine as a pump is described particularly in conjunction with FIGS. **1** to **5**. When the pump input shaft **11** is driven in a clockwise direction, viewed from the shaft end of the pump and as indicated by the arrow A in FIG. **1**, the eccentric center, or eccentric axis **20**, rotates clockwise, arrow A of FIG. **1**, about the shaft or machine axis **19**. For convenience in describing the operation, we have indicated the position shown in FIG. **1** with the eccentric center **20** below shaft axis **19** as the zero degree angular position. The angular position of the eccentric center about axis **19** on moving from the zero degree position clockwise 90°, 180° and 270° is indicated by the dotted radii and the legends 0°, 90°, 180° and 270° indicating these positions of the eccentric center about axis **19**. Only the shaft **11** and the eccentric **21** thereon is rotatably driven from a suitable source of power and thus has continuous rotation. The spider, due to the fact that its movement at the center is in the eccentric path and radially outward of the center is controlled by orbiting means, the cranks **87** connected to the spider and by the ring **81** to the housing, has a limited path of bodily orbiting movement, a combination of reciprocating and transverse oscillating movement. The orbiting means thus controls orbiting movement of the spider and the pistons fixed thereon in relation to the fixed support housing and transmits reaction forces of excursion movement E, FIG. **4**. Since the crank throw or the distance between the pins **86** and **88** is the same as the eccentric distance, the distance between shaft axis **19** and eccentric axis **20**, all positions of the spider piston center line during orbiting movement are parallel to each other. The full capacity positions of the pistons are illustrated in FIGS. **1**, **4** and **5**. The center line of piston P is on the vertical line B or radius through both the shaft and eccentric centers **19** and **20** in the bottom position at 0° and as shown at the top 180° position in FIG. **1**. As indicated in FIG. **4** the piston center line is on center line B for the 0° and 180° positions, and on center line C in the 90° position shown in solid lines and on center line D in the 270° position shown in dotted lines which are all parallel. Thus, as the eccentric center **20** moves from the 0° position, FIG. **1**, through the 90° position, solid lines in FIGS. **4** and **5**, to the 180° position, piston P moves from bottom dead center as shown in solid lines (FIG. **1**) to the top dead center position. With continued eccentric rotation from the 180° position through the 270° position, dotted lines in FIGS. **4** and **5**, to the 0° position, the piston returns to the bottom dead center position shown. Thus, the piston moves in a circular orbiting path providing a combination of both radial reciprocating movement and to and fro or transverse bodily movement from the central position at the 90° and 180° position, illustrated in FIG.

1 at the 180° position. The spherical piston fits in the cylinder and causes excursion or rotary oscillating movement of the cylinder on the cylindrical bearing ring concentric with shaft axis **19**. Thus the spider and pistons and cylinders do not continuously rotate. Since the cylinder bore axis is radial to the cylindrical bearing base of the cylinder it is also radial to the bearing ring. Since the spherical piston seals the cylinder in a plane perpendicular to the cylinder axis, the summation vector of force transmitted is on the cylinder axis radial to the bearing ring and thus through the shaft axis **19**. Accordingly, the force delivered by, as in a pump or to, as in a motor, the eccentric **20** at axis **19** has a reaction grounded by cranks **87**. At the 90° position, the piston **37** and the cylinder **41** which is carried with it is at the left as shown in solid lines in FIG. **4** and with 180° of movement to the 270° position moves to the opposite side of center to the dotted line position through an excursion distance E Thus in eccentric rotary positions 0°, 90°, 180° and 270° the piston axis is respectively in parallel positions B, C, B and D and the cylinder axis is respectively in radial positions B', C', B' and D'. Note that piston axis B and cylinder axis B' are identical. This excursion movement of the piston and cylinder **41** relative to the fixed bearing ring **45** controls the valve porting. With the eccentric in the 0° position shown in FIG. **1**, and rotating clockwise, arrow A, the pressure port **56** in ring **45** is just opening to the pressure port **61** in the cylinder head and remains opened as the cylinder moves to the full line position C', FIG. **5**, at 90° and closes at the 180° position B' with the cylinder in the top dead center position, illustrated in FIG. **1** by the dotted line cylinder **P1**. As the cam continues to rotate from the 180° position through the 270° position D' and then to the 0° position, the pressure port **56** remains closed since the pressure port **61** in the cylinder is to the right of it, as shown in dotted lines in FIG. **5**. The suction ports have an opposite cycle, as shown in FIG. **4** and with the cam in the 0° position the suction port **57** is just closed and remains closed as the eccentric moves through the 90° position C' (solid lines) to the 180° position. On continued movement of the cam past the **180°** position, suction port **57** opens to the port **62** and remains opened on continued rotation through the 270° position D' (dotted lines) to the 0° position where it closes.

The capacity of this pump may be varied by rotating the control ring **81** to change the position of the cranks relative to the housing and thus rotatably or angularly varying the position of the excursion or rotary oscillating movement of the cylinder relative to the ports in the bearing ring **45**. In the configuration shown, when the control ring is in the full capacity position, as shown in FIGS. **1**, **4** and **5**, the overlap period when both pressure and suction ports are closed is only at the 0° and 180° position and the pressure and suction ports are each open for substantially 180° of eccentric rotation. When the control ring is rotated clockwise like arrow A, the overlap is increased to the same degree so that the port openings occur in prgressively reduced portions of the excursion movement of the cylinders or during progressively reduced portions of the angular movement of the cam center **20** about axis **19**. The port opening portion of angular movement is centered about the 90° and 270° positions.

FIGS. **2** and **3** illustrate such stroke adjustment to the zero capacity, or fully unloaded position. The axis of piston **37** and cylinder **41** in the 0° and 180° positions, cylinder axis B', is thus displaced or rotated clockwise as shown in FIGS. **2** and **3**. The cylinder axis C' for the 90° position and D' for the 270° position, are similarly displaced but remain equally spaced to the 0° and 180° position axis B'. The piston axis has similar parallel positions during excursion movement. The piston **34** and cylinder **41**, during excursion movement between the solid line 90° position and dotted line 270° position, have the same excursion movement E, however, as shown in FIG. **2**, the suction port **57** in the ring **45** is always open to the suction port **62** in the cylinder **41**. The pressure port **56** as shown in FIG. **3**, is always closed with respect to the pressure port **61** in the cylinder **41**. Thus, there is no delivery of pressure fluid and with the suction on low pressure port **57** always opened throughout 360° of movement of the cam **21**, there is no pumping action. The other pistons and cylinders function in the same way.

Each of the pistons, cylinders and porting means on the cylinder base and bearing ring consecutively function in the same way to provide when operating as a pump continuous delivery of fluid from the inlet port **68** to supply fluid under pressure to the outlet port **74**. When pressure is supplied to the inlet port the machine will similarly function as a motor.

The fluid pressure orbiting piston and oscillating cylinder machine illustrated in FIGS. **10** to **13** is particularly suited for use as a compressor and has an input pulley **111** secured by suitable fastener **112** and splines **113** to the input or power shaft **114**. Shaft **114** has an inner end eccentric portion **116** with a cylindrical bearing surface **117** for the needle bearing **118** fitted within the central bore **119** of the oscillating spider **121**. The shaft is supported within a cylindrical bearing support sleeve portion **122** which extends inboard and outboard of the sidewall **123** of the housing **124**. The shaft **114** has an inboard cylindrical bearing portion **126** cooperating with the needle bearing **127** secured in the inboard portion **128** of the sleeve **122**. Adjacent to this bearing a reduced diameter sealing portion **131** of the sleeve **122** cooperates with an O ring **132** for a first seal. The outboard end of the shaft **114** is supported by a roller bearing **133** fitted in the outboard portion **134** sleeve **122**. Between the shaft bearings, there is a spring biased shaft seal structure **136** which has a portion **137** secured and sealed within the sleeve **122**. The rotating seal portion **138** has an O ring seal **139** and biasing spring **141** all rotating with the shaft and held by the spring in engagement with an abutment on the shaft and the rotating face seal **142** which engages fixed seal **137**.

The spider **121** has an inner ring portion **146**, a plurality of hollow lightweight radial arms **147** which are axially offset to reduce the axial length of the machine. Each of the arms **147** has an annular lip flange portion **148** which receives the piston member **149** which has a closure plate portion **151** and an annular flange portion **152** having a spherical piston surface **153**. This piston member **149** is secured by snap ring **154** to the arm **147**. The sperical piston surface **153** has a sealing fit in the cylinder bore **156** of the cylindrical portion **157** of the cylinder **158**. Cylinder **158** also has a base portion **159** having a transverse cylindrical bearing surface **161** in bearing engagement with the inner cylindrical bearing surface **162** of the bearing ring **163** which is fixed within the cylindrical wall portion **164** of the cover portion 165 of the housing 124. The suction or inlet pipe 166 is connected through cylindrical wall 164 to an annular manifold passage 167 between the housing cylindrical wall 164 and in a recess in the bearing ring 163. Seals 168 on opposite sides of this annular passage seal the passage. The lower portion 171 of housing 164 is enlarged to provide a storage chamber 172. The housing portion 165 and the housing portion 124 at their meeting edge have flanges 173 engaged by a U-shaped loop clamp 174 to secure the parts together.

At each pumping station for each cylinder the manifold is connected by a passage 176 extending from the manifold to the bearing surface 162 of the bearing ring 163. The cylinder base 159 has a closure portion 177 closing the port 176 at times and at other times the port 176 connects to the cylinder bore 156 which, as pointed out above, is opened at both ends except for closure by the piston. The piston cover portion 151 has two outlet ports 181, as best shown in FIG. 11, both covered by the enlarged end 182 of the leaf spring valve 183. A rigid guide plate 184 is located at the back of the valve spring 183 and both this plate and the valve spring are secured by suitable fasteners 186 to the underside of the piston head, or cover. When outlet pressure reaches the desired value, leaf spring valve 183 is deflected permitting flow from the pumping chamber through ports 181 to the interior of the housing. The backing member 184 limits and defines this flexing movement of the leaf spring valve 183 for a long life spring valve. The interior housing chamber 188 receiving the pumped fluid has an outlet passage 189 to supply fluid.

A pair of double spring rings 191 engage the side flange portion 192 of the base 159 of the cylinders 158 to hold the cylinders against the bearing ring 163 when the pressure is not present to do so.

The capacity control mechanism has a control ring 196 rotatably mounted on an external bearing surface 197 upon the housing support sleeve portion 122. A plurality of crank members 198 have one pin portion 199 extending into and rotatably mounted in bearing bores 201 in the spider and another crank pin 202 extending into and rotatably mounted in bearing bores 203 in ears 204 of the control ring 196. Between a pair of ears 204 there is a stop cam 206 having a pair of opposed shoulders 207 and 208 cooperating with a pin 209 fixed in the wall 123 to limit rotary movement of the control ring 196. The control ring 196 also has an arm 211 having a ball socket 212 to receive the ball end 213 of the lever 214 which is fixed in a transverse bore 216 in the control shaft 217 and thus perpendicular to this shaft. The control shaft is rotatably mounted and sealed in a radial bore 218 in the wall portion 123 of the housing and extends radially outside the housing where is has secured thereto an actuating lever 219 or capacity control lever 219.

A space around shaft 114 in sleeve 122 between the seals 132 and 136 is connected by a port 221, a passage 222 through the control shaft 217, a passage 224 in the manifold 163 and to the inlet annular chamber 167 in order to connect the space between the bearings to vent the leakage space to the low pressure inlet of the compressor.

In the machine illustrated in FIG. 10 to 13, the eccentric axis 226 is offset the same distance from the machine axis 227 as the throw of the crank 198 so the spider 121 and its pistons has the same oribiting movement as the above described machine, illustrated in FIGS. 1 to 9. As in the machine of FIGS. 1 to 9, in the FIGS. 10 to 13 machine, the bearing ring 163 is similarly centered about the machine axis, the cranks 198 are pivoted by pin portions 198 in openings 201 in the spider concentric with the eccentric axis 226, the other crank pin 202 is pivoted in openings 203 concentric with the machine axis 22 and the cylinder bore axis is radial relative to the cylindrical cylinder base and bearing ring internal bearing surface. When this machine is driven clockwise, as viewed when facing the shaft and from the other end of the machine counter-clockwise as indicated by the arrow H, in FIG. 10, the suction ports 176–175 will be similarly closed as the eccentric rotates about the shaft axis from the 0° position through the 90° position to the 180° position which is the pressure stroke during which the piston moves from bottom to top dead center, the position shown in FIG. 10. The suction ports 176–175 then will open as the eccentric continues to rotate past the 180° position through the 270° position to the 0° position providing the suction stroke as the piston moves from top to bottom dead center. The pressure stroke occurs during the time when the inlet port 176 is closed by the base portion 177 of the cylinder and will cause pressure developed in the contracting operating chamber to open the check valve 183 to deliver fluid to the outlet. The check valve 183 will be closed by the outlet pressure during the suction stroke. In FIG. 10 the piston head 151 is shown at the top dead center of stroke, or the 180° position, having just delivered fluid through the valve 183 to chamber 188 in the housing 124. During continued rotation from the 180° position through the 270° position to the diametrically opposite 0° position of the cam center axis 226 about the shaft axis or center 227 in the direction of arrow H, the suction port 176 remains opened for the suction stroke. At the 0° position, the piston head 151 will be in the bottom dead center position and then on continued rotation of the cam from the 0° position through the 90° position to the 180° position, the piston will move from bottom dead center to the top dead center position illustrated in FIG. 10 providing the discharge or pressure stroke forcing compressed fluid through the outlet valve 183.

Movement of the control ring 196 in the same direction as the direction of rotation H will, as in the above modification shown in FIGS. 1 to 9, move the oscillation center so that the inlet or suction port 176 is opened for a longer period of time, thus reducing the pressure a discharge stroke portion and gradually reducing the capacity of the machine or the output of the device as a pump. In the unloaded or zero capacity position of the capacity control ring 196, the suction port 176 remains open at all times or through 260° of movement of the eccentric so that there is no pumping action.

It will be appreciated that the above disclosed specific embodiments are subject to modification in accordance the the teachings of this invention.

It is claimed:

1. In a hydraulic machine; a support housing including a bearing ring fixed on said housing having an internal bearing surface circular about a shaft axis; a shaft mounted on said housing for rotation about the shaft axis and having an eccentric bearing portion rotating with said shaft and having an eccentric axis rotating about said shaft axis during rotation of said shaft; a spi-

der having a central portion mounted on said eccentric bearing for rotation of said shaft eccentric bearing portion relative to said spider and having a plurality of arms rigidly fixed to the central portion and extending outwardly and each arm having a sperical piston and each piston being located at a radially offset piston station; orbiting means connected to said housing and said spider to provide a path of orbiting movement, a combination of a limited extent of radially reciprocating and rotary oscillating movement, of each of said pistons in its piston station relative to said bearing ring in coordination with movement of said central portion of said spider and rotation of said eccentric bearing portion; a cylinder on each piston having a bearing base slidably mounted on said internal bearing surface of said bearing ring and a cylindrical bore extending radially inwardly of said internal bearing surface and fitting on the sperical piston providing a variable volume chamber therebetween varying with said radially reciprocating movement of said piston and providing rotary oscillating movement of said cylinder on said internal bearing surface in response to rotary oscillating movement of said piston; and fluid supply and control means on said cylinder and said housing for providing and controlling flow of fluid to and flow of fluid from said chamber in response to said rotary oscillating movement of said cylinder in phase relation to said radially reciprocating movement of said piston.

**2.** The invention defined in claim **1** and means to control said orbiting means to rotatably adjustably displace said path of orbiting movement to cause rotary adjustment of said rotary oscillating movement of said cylinder relative to said bearing ring to change the time of opening and closing of said ports relative to radial reciprocating movement of said pistons to vary machine capacity.

**3.** The invention defined in claim **1** and said fluid supply and control means including a port for each cylinder in said bearing ring and a port in each cylinder base controlled by said rotary oscillating movement of said cylinder to open and close fluid communication between said ports for controlling a flow.

**4.** The invention defined in claim **1** and means to control said orbiting means to adjust said path of orbiting movement to cause said rotary oscillating movement of said cylinder to change to vary the control of said fluid supply and control means to vary machine capacity.

**5.** In a hydraulic machine; a support housing including a bearing ring fixed on said housing having an internal bearing surface circular about a shaft axis; a shaft mounted on said housing for rotation about the shaft axis and having an eccentric bearing portion rotating with said shaft and having an eccentric axis rotating about said shaft axis during rotation of said shaft; a spider having a central portion mounted on said eccentric bearing for rotation of said shaft eccentric bearing portion relative to said spider and having a plurality of arms rigidly fixed to the central portion and extending outwardly and each arm having a spherical piston and each piston being located in a radially offset piston station; orbiting means connected to said housing and said spider to provide orbiting movement, a combination of radial reciprocating and rotary oscillating movement, of each of said pistons in its piston station relative to said bearing ring in coordination with movement of said central portion of said spider and rotation of said eccentric bearing portion; a cylinder on each piston having a bearing base slidably mounted on said internal bearing surface of said bearing ring and a cylindrical bore extending radially inwardly of said internal bearing surface and fitting on the spherical piston providing a variable volume chamber therebetween varying with said radial reciprocating movement of said piston and providing rotary oscillating movement of said cylinder on said internal bearing surface in response to orbiting movement of said piston; fluid supply and return means; port means, including a port in said internal bearing surface of said bearing ring and a port in said cylinder base selectively aligned for open fluid communication and misaligned to close to block fluid communication responsive to rotary oscillatory movement of said cylinder, for controlling flow of fluid between said fluid supply and return means and said chamber in phase with said radial reciprocation of said piston.

**6.** The invention defined in claim **5** and said orbiting means having adjustment means to rotatably displace the orbiting movement of said piston to rotatably displace the rotary oscillating movement of said cylinder to control said port means to vary the period in which said ports are aligned for open fluid communication and misaligned to block fluid communication during each revolution of said shaft to vary machine capacity.

**7.** The invention defined in claim **6** and said adjustment means being rotatable control ring mounting said orbiting means on said housing and being rotatable to vary machine capacity.

**8.** In a hydraulic machine; a support housing; a shaft mounted on said housing for rotation about a shaft axis and having an eccentric bearing portion rotatable with said shaft having an eccentric axis rotating about said shaft axis during rotation of said shaft; a spider having a central portion having an aperture mounted on said eccentric bearing for rotation of said shaft eccentric bearing portion in said aperture and having a plurality of arms extending outwardly and each arm having a spherical piston equally spaced from said eccentric axis and each piston being located in a radially offset piston station; orbiting means connected to said housing and said spider to provide orbiting movement, a combination of radial reciprocating movement and rotary oscillating movement, of each of said pistons in its piston station relative to said housing in coordination with eccentric movement of said central portion of said spider and rotation of said rotating eccentric bearing portion; a bearing ring fixed on said housing having an internal cylindrical bearing surface concentric with said shaft axis; a cylinder on each piston having a cylindrical bearing base fitting said internal cylindrical bearing surface of said bearing ring for sliding rotary movement and a cylindrical bore extending radially inwardly of said internal cylindrical bearing surface and fitting on the spherical piston providing a variable volume chamber therebetween varying with said radial reciprocating movement of said piston and providing rotary oscillating movement of said cylinder on said internal cylindrical bearing surface in response to rotary oscillating movement of said piston; fluid supply and return means; port means, including a port in said internal surface of said bearing ring and a port in said cylinder base selectively aligned for open fluid communication and misaligned to close to block fluid communication between said fluid supply responsive to oscillatory movement of said cylinder, for controlling flow of fluid between said fluid supply and return means and said chamber in phase with said radial reciprocation of said piston.

**9.** In a hydraulic machine; a support housing; a shaft mounted on said housing for rotation about a shaft axis and having an eccentric bearing portion rotatable with said shaft and having an eccentric axis rotating about said shaft axis during rotation of said shaft; a spider having a central portion having an aperture mounted on said eccentric bearing for rotation of said shaft eccentric bearing portion in said aperture and having a plurality of arms rigidly fixed to the central portion and extending radially outwardly from said eccentric axis and each arm having a spherical piston equally spaced from said eccentric axis and each piston being located in a radially offset piston station; a crank assembly having crank with a shaft at one end rotatably connected to said housing and a shaft at the other end rotatably connected to said spider to provide and control orbiting movement, a combination of radially reciprocating and rotary oscillating movement, of each of said pistons in its piston station relative to said housing in coordination with the eccentric movement of said central portion of said spider by said eccentric bearing portion; a bearing ring fixed on said housing having an internal cylindrical bearing surface concentric with said shaft axis; a cylinder on each piston having a cylindrical bearing base fitting said internal cylindrical bearing surface of said bearing ring for rotary sliding movement and a cylinder bore extending radially inwardly of said internal cylindrical bearing surface and fitting on the spherical piston providing a variable volume chamber therebetween varying with said radial reciprocation of said piston and providing rotary oscillating movement of said cylinder on said internal cylindrical bearing surface in response to said orbiting movement of said piston; fluid pressure supply and return means; port means, including a port in said inner bearing surface of said bearing ring and a port in said cylinder base selectively aligned for open fluid communication and misaligned to close to block fluid communication responsive to rotary oscillatory movement of said cylinder, for controlling flow between said fluid supply and return means and said chamber in phase with said radial reciprocation of said piston.

**10.** The invention defined in claim **9** and said crank having a throw distance equal to the eccentric distance between said shaft axis and said eccentric axis.

**11.** The invention defined in claim **9** and a port through said piston; a one-way leaf spring valve controlling said port in said piston.

**12.** The invention defined in claim **9** and said bearing ring having an inlet and outlet port for each cylinder and an inlet and outlet port in each cylinder base.

**13.** The invention defined in claim **9** and said crank assembly including means to rotatably displace the orbiting movement of said piston to rotatably displace the oscillating movement of said cylinder to control said port means to vary the period said ports are aligned for open fluid communication and misaligned to block fluid communication during each revolution of said shaft to vary machine capacity.

**14.** The invention defined in claim **13** and a rotatable control mounting said shaft at one end of said crank on said housing and being adjustably rotatable to vary machine capacity.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,777,622 Dated December 11, 1973

Inventor(s) Gilbert K. Hause et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

**In the specification, column 1, line 41 "portion" should be -- porting --; column 4, line 67, "90°" should be -- 0° --; column 5, line 60, "prgressively" should be -- progressively --; column 8, line 54, numeral "260°" should be -- 360° --; column 8, line 59, "the" first occurrence, should be -- with --.**

**In the claims, column 10, claim 7, line 28, insert -- a -- before "rotatable".**

Signed and sealed this 14th day of May 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents