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Culberson

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[54] **RADIAL PISTON HYDRAULIC PUMP OR MOTOR WITH LOW LOSS REACTION LINKAGE**

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[52] **U.S. Cl.** **91/495,** 92/58

[51] **Int. Cl.** **F01b 1/06,** F01b 13/06

[58] **Field of Search** 92/56, 57, 58; 91/495; 417/273

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[57] **ABSTRACT**

A radial piston hydraulic pump or motor characterized by a new linkage assembly interposed between the pistons and the reaction assembly. The linkage assembly, in addition to transmitting forces between the pistons and the reaction assembly, also stabilizes the pistons relative to the cylinders. The linkage assembly is characterized particularly by the incorporation of a parallel pair of Scott-Russell linkages, some portion of the parallel pair being guided for linear reciprocal movement by reason of the parallel nature of the links.

13 Claims, 12 Drawing Figures

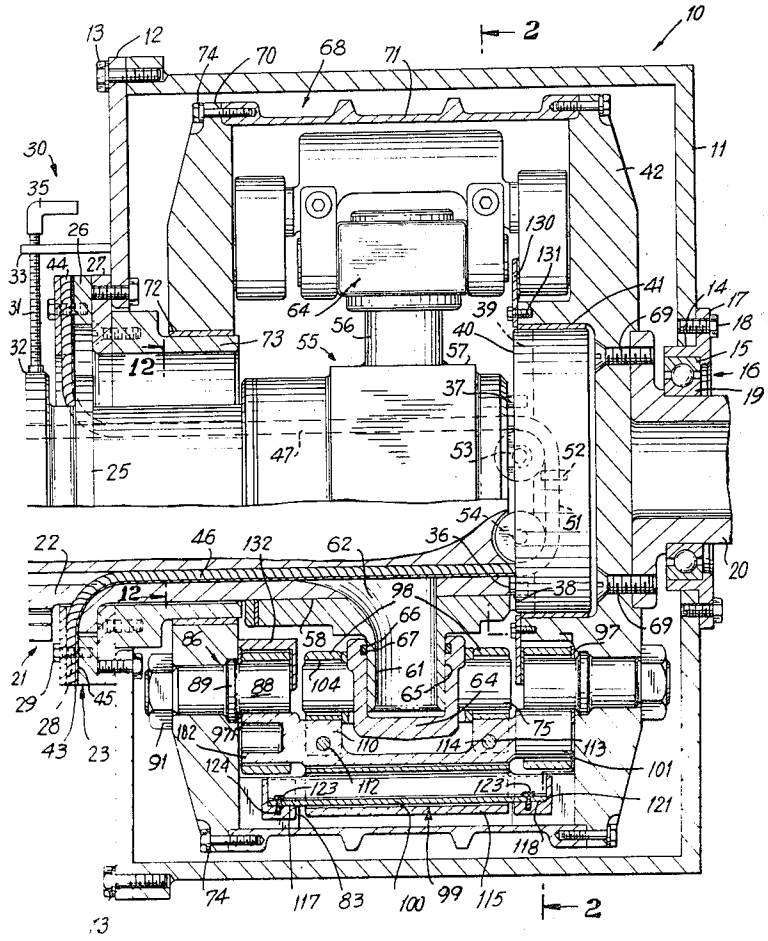
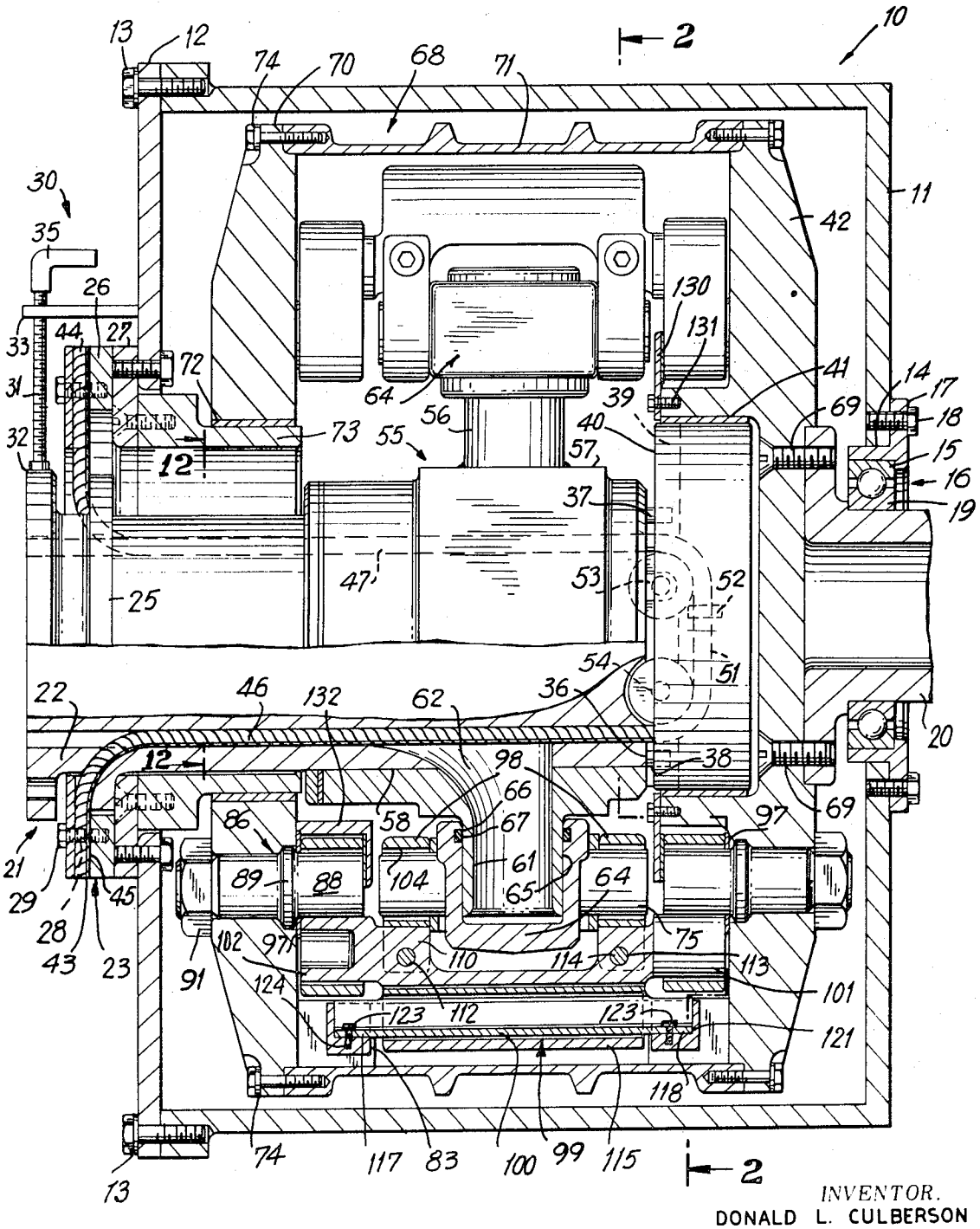


FIG. 1

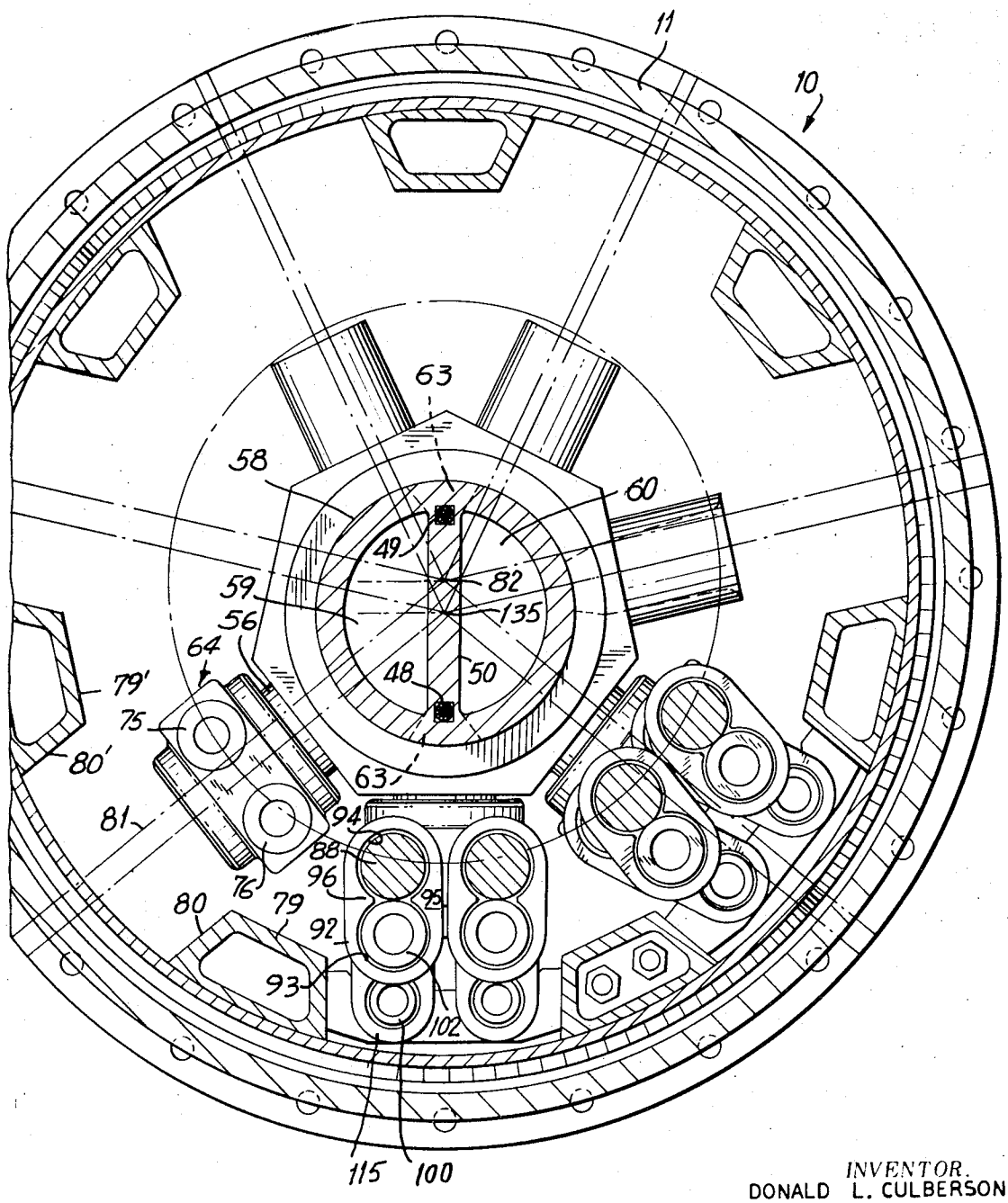


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FIG. 2



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FIG. 4 FIG. 5

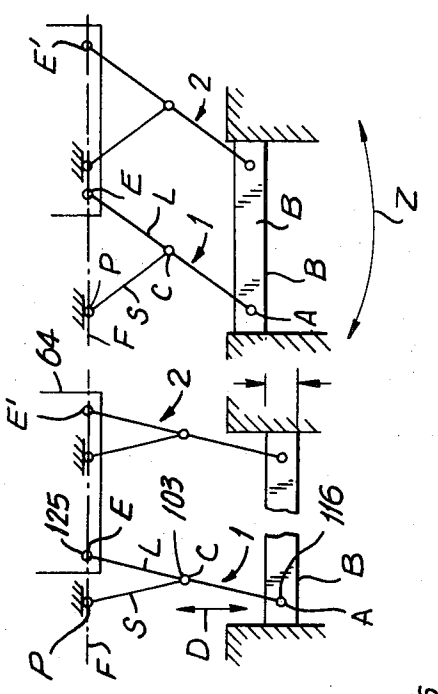
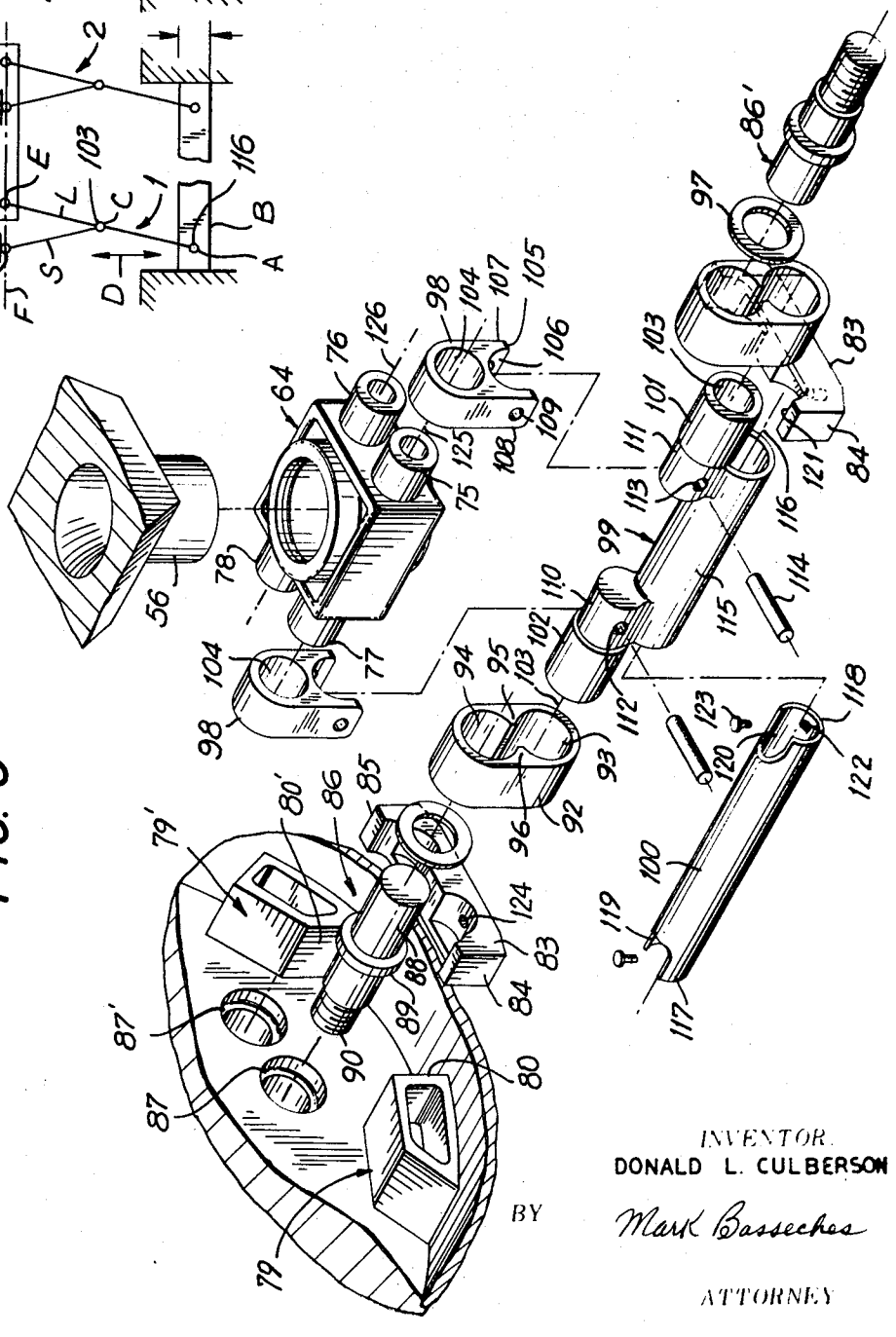


FIG. 3



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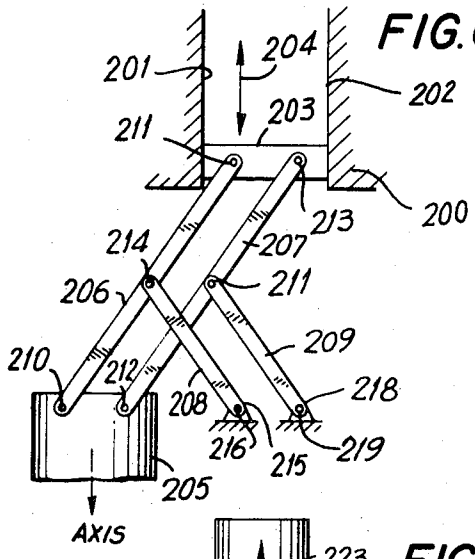


FIG. 6

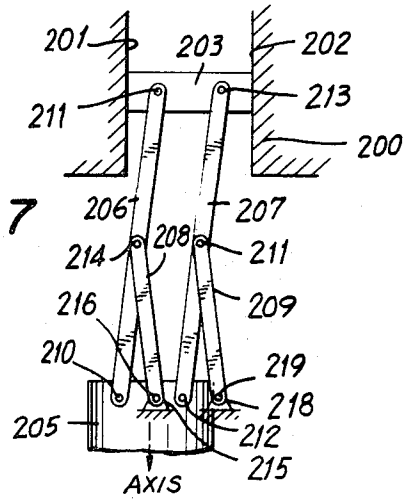


FIG. 7

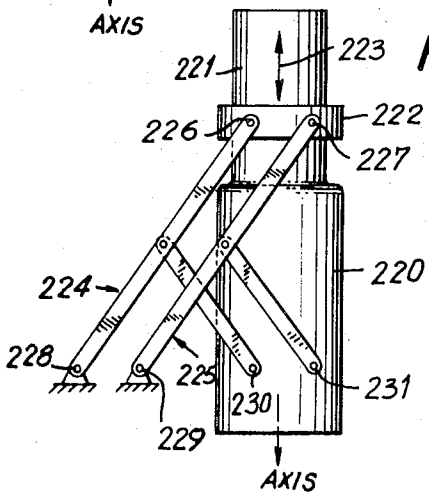


FIG. 8

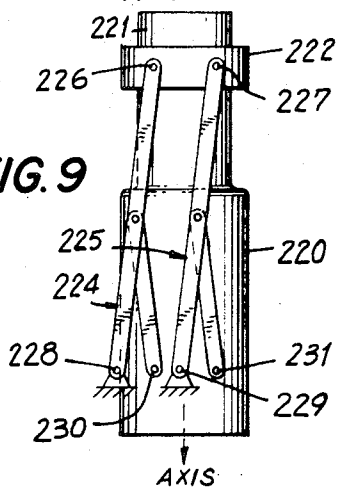


FIG. 9

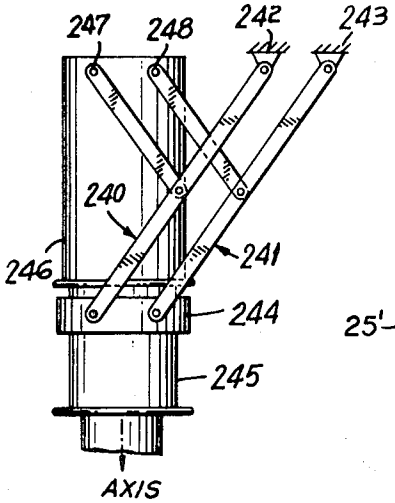


FIG. 10

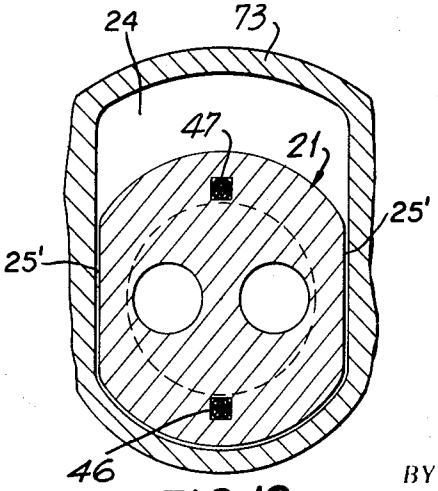


FIG. 12

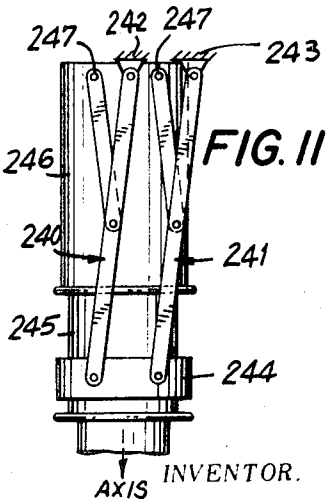


FIG. 11

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RADIAL PISTON HYDRAULIC PUMP OR MOTOR WITH LOW LOSS REACTION LINKAGE

BACKGROUND OF THE INVENTION:

1. Field of the Invention

This invention is in the field of radial piston hydraulic pumps and motors of the type in which a pintle shaft is provided with outwardly opening fluid supply manifolds for fluids under high and low pressure, respectively, the manifolds being separated by land portions. A block having cylinder bores is rotatably mounted over the pintle shaft in sealing relation of the manifolds or discharge areas, the block including passageways extending from a central bore in the block to the individual cylinder chambers in the block. By the described arrangement, the cylinder chambers are sequentially connected to the high and low pressure manifold or discharge portions of the pintle shaft as the block rotates about the shaft.

Pistons are sealingly disposed on the cylinder block to define with the cylinders variable displacement chambers. A reaction assembly is provided for guiding the pistons in an eccentric path relative to the axis of rotation of the block, As the pistons proceed in the eccentric path, they shift axially inwardly and outwardly of the cylinder bores in the block, thus varying the displacement of the chambers defined between the pistons and the cylinders.

It will be appreciated that the apparatus may be used either as a pump or as a motor. When used as a pump, the block is caused to rotate by a prime mover, whereas when the apparatus is used as a motor, fluid under pressure is admitted to one of the discharge areas of the pintle and power is derived from the resultant rotation.

2. The Prior Art.

Rotary piston pumps and motors operating on the above outlined principles have long been known and widely used in specific applications wherein small size and high efficiency are not significant factors. Although there are many theoretical advantages which suggest the use of rotary piston pumps and motors as gearless transmission systems for automobiles, and analogous purposes, the use of such systems has heretofore been restricted to vehicles of special types by reason of the deficiencies inhering in all pumps and motors heretofore known.

Among the advantages of utilizing rotary piston hydraulic pumps or motors in a vehicle, such as an automobile, there may be mentioned the possibility of permitting the pump to be driven by an engine operating within a relatively restricted torque-speed range, such as an internal combustion engine, and varying the drive speed by varying the displacement of the pump and/or motor or motors, rather than by varying the speed. By avoiding the necessity of increasing and decreasing the speed of the multiple parts of the prime mover which, as will be understood, have substantial inertia, it will be appreciated that better vehicle acceleration may be obtained since the inertia of the components of the transmission assembly is far less than that of the prime mover.

It is well understood that internal combustion engines may be operated highly efficiently if they are permitted to rotate at a fixed speed or in accordance with a predetermined speed-torque program, resulting not only in better fuel economies but also in discharge of less partly burned by-products. The importance of the latter characteristic will be readily understood in view of the present emphasis on exhaust emission controls, and recognition that automotive exhausts are considered to be the largest single source of air pollutants.

In certain types of internal combustion engines, the so-called "Wankel" engine being a prime example, difficulties other than efficiency losses result from the engine being operated outside predetermined optimum speed ranges. The Wankel engine, for instance, by reason of its unusual design, involves great difficulties in sealing the various combustion chambers to prevent "blow-by" or leakage from one chamber to an adjacent chamber, which difficulties are largely relieved so long as the engine operates within a designated speed range.

No attempt has been made herein to catalog all of the various theoretical advantages inhering in the use of radial piston pumps or motors as hydrostatic transmission for automobiles. However, limitations in the performance capabilities of available pumps or motors have precluded such use. In general, the performance deficiencies of hydraulic radial piston pumps and motors may be classified in two categories, namely:

1. flow restrictions, i.e. the ability of a radial piston pump or motor of limited size to permit high volumetric flow rates of hydraulic fluid, and

2. mechanical losses inherent in the design of known pumps and motors.

The problems of flow restriction have, by and large, been solved in accordance with U.S. Pat. Nos. 3345,916 and 3548,719. Thus, the drawbacks in the use of radial piston pumps and motors are now of the second above enumerated type.

Broadly stated, it is a principal objective of the present invention to provide a radial piston pump or motor having an improved force transmitting linkage between the pistons and the reaction assembly whereby losses and deficiencies inhering in reaction ring-piston connections heretofore known are overcome, resulting in the provision of a pump-motor having high efficiency, relative freedom from wear and long life characteristics.

SUMMARY OF THE INVENTION

The invention may be summarized as directed to an improved linkage for communicating forces between the pistons of a radial piston pump or motor and the reaction assembly thereof. The improved linkage comprises at least one pair of Scott-Russell straight line motion linkages, which linkages are arranged in parallel and within a common plane extending through the axis of rotation of the block. The linkages may be oriented in any one of a series of different positions, functioning in each case to relieve the pistons of cocking and/or lateral force moments relative to the cylinders.

In the preferred embodiments, the connection between the pistons and the reaction assemblies is made by the use of two separate pairs of Scott-Russell linkages, the pairs being disposed in parallel planes perpendicular to the axis of rotation of the block and the connections between the pistons and the opposed pair of linkages being symmetrical with respect to the axis of the pistons.

It is accordingly an object of the invention to provide an improved radial piston pump or motor device.

A further object of the invention is the provision of a radial piston pump or motor device wherein mechanical losses are minimized.

Still a further object of the invention is the provision of a device of the type described in which parallel pairs of Scott-Russell linkages are employed as the force transmitting agent between the reaction assembly and the piston members, thereby to relieve the latter of cocking forces or stabilizing functions, whereby efficient use of piston rings may be made.

Still a further object of the invention is the provision of a pump or motor of the type described wherein sliding movement between components subjected to forces normal or substantially normal to the direction of sliding movement is eliminated.

A further object of the invention is the provision of a device of the type described wherein fluid side forces are minimized and wherein balanced dynamic forces are exerted.

Still a further object of the invention is the provision of a device of the type described wherein the provision of accurately machined parts, such as the polygonal reaction plates heretofore required in certain types of apparatuses is obviated, the clearances required being maintained within limits readily achieved and satisfactorily met in such industries as the automobile industry in the manufacture of automotive engines.

A further object is the provision of a device of the class described which eliminates the use of return springs or their equivalent, as is required in certain hydraulic pumps and motors heretofore known.

It is a further object of the invention to provide a device of the class described which lends itself well to the use of non-tilting hydrostatic bearings.

A still further object of the invention is the provision of a device of the class described wherein reaction loads are transmitted to the reaction assembly at portions which are closer to the axis of the pintle shaft than any constructions heretofore known, thereby reducing the over-all diameter of the pump-motor mechanism.

To attain these objects and such further objects as may appear herein or be hereinafter pointed out, reference is made to the accompanying drawings, forming a part hereof, in which:

FIG. 1 is a horizontal sectional view through a radial piston pump or motor of the type described;

FIG. 2 is a section taken on the line 2—2 of FIG. 1, wherein repetitive details of construction of the linkage and cylinder assemblies have been omitted for purposes of clarity;

FIG. 3 is an exploded perspective view of a piston, elements of the reaction assembly, and elements of a linkage assembly;

FIGS. 4 and 5 are diagrammatic views of a linkage assembly embodying the principles of the pump or motor illustrated in FIGS. 1 to 3, in varying positions in the course of the piston stroke;

FIGS. 6 and 7 constitute diagrammatic views of an alternate form of connection between the linkage, reaction assembly and piston, the figures depicting the parts in varying positions during the stroke;

FIGS. 8 and 9 are diagrammatic views showing a still further modification of the manner in which the linkages are interconnected between the pistons and the reaction assembly, the figures depicting the parts in varying positions during the stroke;

FIGS. 10 and 11 are diagrammatic views showing a still further modification in the manner of interposing the linkages between the pistons and the reaction assembly, the figures depicting the parts in varying positions during the stroke;

FIG. 12 is a sectional view taken on the line 12—12 of FIG. 1.

Referring now to the drawings, 10 is a housing within which is mounted a radial piston pump or motor assembly in accordance with the invention, it being understood that the housing will normally incorporate mounting means wherein the same may be fixed in some predetermined relation relative to the apparatus with which it is being used, such as, by way of example, an automobile or other vehicle.

The housing desirably includes an outer shell 11 of cylindrical configuration, closed at one end by a cover plate 12, mounted in position by closure bolts 13. A circular opening 14 is formed at the other end of the shell 11, the outer race 15 of a shaft bearing 16 being supported within an annular bearing support boss 17 secured by bolts 18 within the opening 14. The inner race 19 of the bearing 16 supports the input-output shaft 20 which, in the illustrated embodiment as will be more fully set forth hereinafter, is fixed to the reaction assembly.

The pintle assembly 21 is supported by the housing so as to be laterally movable with respect thereto. The outer or left hand end 22 of the pintle assembly 21 is slidably mounted in a slide block support assembly 23, secured to the end plate 12 of the housing.

The slide block support assembly includes a laterally extending guideway 24, having parallel upper and lower guide wall portions which define the guideway proper.

The the pintle includes an enlarged collar25, the upper and lower surfaces 25', 25' of which are elongated in the lateral direction and intimately engage with the upper and lower parallel walls defining the guideway 24. The guideway 24 is provided with an opening which is elongated in the lateral direction, to provide clearance for the side to side movement of the pintle, while maintaining the pintle axis against tilting in any direction.

It will be readily understood that alternate means of providing lateral movement between the pintle and the housing may be employed.

Optionally, the clearance defining the guideway 24 may be provided through the use of a spacer plate 26, the opening in which is oversized as compared with the complemental openings formed in inner slide plate 27 and outer slide plate 28, respectively forming the inner and outer boundaries of the slideway referred to generally as 24. The plates 26, 27, 28 may be interconnected by bolts 29 or other suitable means.

Means for effecting the lateral shifting movement between the pintle and the housing are interposed between the noted parts. For purposes of simplicity, in the illustrated embodiment the lateral shifting assembly 30 has been shown to comprise a threaded member 31 having an inner end 32 rotatably secured to the pintle in such manner that axial shifting of the threaded member relative to the pintle is prevented. The threaded member 31 passes through a threaded post 33 affixed at 34 to the housing, an adjustment knob 35 being provided for rotation of the screw and con-

sequent lateral shifting movement of the pintle. It will be appreciated that in actual practice such lateral movement may be effected by any of a series of hydraulic, manual or automatic adjustment control mechanisms. Similarly, it will be appreciated that in certain instances where variable displacement is not required, the pintle may be locked permanently with its axis displaced a fixed distance from the axis of the reaction assembly, in which case no adjustment mechanism and, indeed, no slide mechanism need be provided.

The inner end 36 of the pintle assembly includes a pair of axially directed stabilizer pins 37, 38, which function, by sliding engagement within a complemental, transversely extending slot 39 formed in floating bearing block 40, to limit upward and downward relative movement between the pintle and the block 40, when viewed in the orientation of FIGS. 1 and 2. The block 40 is disposed within an annular recess 41 formed within the right handmost reaction plate 42.

The inner end 36 of the pintle assembly is stabilized against displacement from the plane of the section of FIG. 1 by engagement of the pins 37, 38 in the slideway 39 formed in the block 40 and against transverse movement by a lateral stabilization assembly which is the subject of a patent application filed on even date herewith and entitled Radial Pump or Motor with Stabilized Pintle and, hence, a full description thereof is beyond the scope of the present description.

Briefly stated, the stabilizer includes a flexible cable or cables 43 of fixed over-all length, the distal ends 44, 45 of which are fixed with relation to the housing. The cable includes transversely extending portions adjacent the ends, turning gradually to axially extending branches 46, 47 slidably extending within slots 48, 49 within the body of the pintle and in line with the land defining bridge portion 50 thereof — see FIG. 2. The cable includes a transversely extending central branch portion 51 which is made fast at 52 to the block 40, the cable junction between the axially directed branches 46, 47 and the laterally directed portion 51 being passed over rollers 53, 54 or like anti-friction members carried by the innermost end of the pintle.

It will be recognized from the foregoing that, in view of the fixed length of the cable, a lateral shifting movement of the pintle will result in extension of one branch of the cable and a concomitant diminution of the length of the other branch, the end result of which cable arrangement is to stabilize the inner end of the pintle relative to the housing in an improved manner as contrasted with a purely cantilevered arrangement. It will be appreciated that a cantilevered structure will operate satisfactorily and that the stabilizing arrangement described need not be employed to realize the advantages of the present invention.

A cylinder block assembly 55, in accordance with known practice, is rotatably mounted on the pintle shaft. The cylinder block assembly of the present apparatus includes a spoke-like series of cylinder bosses 56 projecting radially from a central hub portion 57, which hub is provided with the usual axial bore 58. As is conventional in radial piston pumps and motors, the bore 58 intimately engages and surrounds the radial, outwardly open manifold or discharge area 59, 60 of the pintle shaft, to provide communicating passageways between the discharge areas and the cylinder bores 61.

Optionally but preferably, the passages or transition areas 62 in the cylinder block which adjoin the pintle shaft and lead or conduct fluid from the shaft to the bore portions 61 of the cylinders proper are elongated in their axial dimension and reduced in their angular dimension, in accordance with the teachings of U.S. Pat. Nos. 3,345,916 and 3,548,719 so as to provide an improved flow path between the cylinders and the pintle.

It will be further appreciated that the conventional configuration of passageway may be employed, while still retaining certain of the benefits of the present invention.

In accordance with conventional practice, the land areas 63, which are shown in dot and dash lines in FIG. 2, have their peripheral portions of a somewhat greater arcuate extent than the arcuate extent of the passages 62 at the bore 58 of the block so that as the passages traverse the lands, the passages are sealed by the lands and there is no possibility of a bridging of the passage between the charge and discharge areas of the pintle shaft.

In the embodiment illustrated in FIGS. 1 and 2, the seal between the pistons and cylinders is effected between the external surface of the cylinder and the internal bore portions of the piston assemblies 64 which are essentially cup-like. However, it will be appreciated that the apparatus of the present invention is fully usable with conventional pistons riding on and sealing the internal surfaces of the cylinders.

Optionally but preferably, the interior surfaces 65 of the pistons may be provided with an annular groove or grooves 66, within which may be seated one or more piston rings 67. It will further be evident that while the rings are shown as mounted in grooves formed in the pistons, it is equally practicable to form the ring retaining grooves on the external surfaces of the cylinders, or rings may be mounted on both the pistons and the cylinders.

It will further be appreciated that fluid is conducted to and from the chambers 59 and 60 through input and output conduits (not shown) which are preferably flexible, to facilitate displacement of the pintle, and which are led to the chambers through the outer end 32 of the pintle shaft assembly 21.

Operating forces in the pump-motor are exerted between the pistons and the reaction assembly 68 next to be described.

The reaction assembly includes the previously mentioned inner reaction plate 42 which is fixed by bolts 69 to the shaft 20, outer reaction plate 70, and a cylindrical reaction shell 71 which interconnects plates 42 and 70. The plate 70 is mounted, as by bearing 72, on a cylindrical shaft extension portion 73 of the slide block support assembly 23. A series of machine screws 74 extending through apertures in the plates and into complementally tapped apertures in the shell 71 may be employed to interconnect these parts.

It will be appreciated that the radial piston reaction pump-motor device as heretofore described is essentially conventional in its construction with the exception of the pintle stabilizing mechanism hereinabove generally described.

The essential novelty of the present invention lies in the linkage mechanism which is employed to interconnect the pistons with the reaction assembly 68 in a manner which will be hereinafter described in detail.

The linkage in each instance comprises two or more straight line mechanisms of the type known as Scott-Russell linkages. To facilitate an understanding of the detailed showing of the linkages, reference will initially be made to the diagrammatic showings of FIGS. **4** and **5**.

In each such view there is shown a pair of Scott-Russell linkages **1** and **2**, each of which linkages is comprised generally of a long link L, a short link S, and a slide block B. The effective length of the short link is one half the effective length of the long link. The distal ends of the long link L are pivotally connected to the slide block and to the piston assembly **64**. One end of the short link S is pivotally connected to the reaction assembly at point P and the other end to the center point C of the long link L.

It is a property of a Scott-Russell linkage that when the pivotal connection point A of the long link L is moved toward or away from the point P in the direction of the line D, that the opposite end E of the long link L will be shifted precisely along a linear locus represented by the line F. It will thus be apparent that with two Scott-Russell linkages **1** and **2** disposed in parallelism, as the slide block B is moved within the guideway provided therefor, in the direction of the line D, the free ends E, E′ will always remain on the line F. In view of the fact that the pistons **64** have two points of connection, E and E′, to the linkages, it will be apparent that the pistons will be supported against tilting and will be stabilized in space and their axes will at all times be perpendicular to the line F.

As hereinafter used in the application and claims, the term "Scott-Russell linkage" is intended to refer to a linkage assembly as shown at **1** and **2** of FIG. **4**, comprising, as noted, a long link and a short link, the effective length of the short link, e.g. the distance between pivots, being one half of the effective length of the long link, e.g. the distance between pivots.

Reference to a "pair" or "parallel pair" of such linkages is intended to refer to two such linkages which lie in a common plane or act as if they lay in a common plane perpendicular to the axis of rotation of the cylinder block, the linkage of the pair being offset angularly within such plane. An example of such a "pair" of linkages is shown in FIGS. **4** and **5** wherein the arcuate segment Z indicates the directions of rotation of the block and reaction assembly.

While it is feasible to connect the pistons to the reaction assembly through the use of a single parallel pair of Scott-Russell linkages, which linkages might lie in a plane extending through the common axes of the cylinders and projecting outwardly to a surrounding reaction assembly, it has been determined to be preferable to employ two parallel pairs of Scott-Russell linkages for controlling each piston, one pair being disposed adjacent each side of the piston.

In the light of the foregoing general description, reference will be made especially to FIGS. **1** to **3** for details of the specific linkage constructions herein employed.

As best seen from FIG. **3**, each piston assembly **64** includes four integral, outwardly extending stub shafts **75**, **76**, **77**, **78**. The stub shafts **75**, **77**, and the stub shafts **76**, **78** are coaxial, all of the shafts being parallel to the axis of rotation of the cylinder block.

It will be appreciated from a comparison of FIGS. **3** and **4** that the axes of the shafts **75**, **77** correspond with the pivot point E in FIG. **4**, and the axes of the shafts **76**, **78** with the pivot point E′.

The reaction plates **42** and **70** are integrally formed with a plurality of truncated segments **79**, **79′**. The opposed or facing wall portions **80** and **80′** of each adjacent pair of segments are parallel with each other and with a line **81** extending from the axis of rotation **82** of the reaction assembly—see FIG. **2**. It will thus be seen that the opposed faces or walls **80**, **80′** define guideways corresponding to the guideways shown in FIGS. **4** and **5**, which assure radial movement of the center point of the slide block B relative to the axis of rotation **82** of the reaction assembly.

The structures corresponding to the slide block B in the diagrammatic view, FIG. **4**, are shown at **83**, **83**. As best appreciated from an inspection of FIG. **3**, the slide blocks **83**, **83** include parallel end walls **84**, **85** which slidably engage against opposed walls **80**, **80′** defining the slideways, the described interfit assuring that the center point of the slide blocks **83**, **83** is constrained to move in a purely radial direction relative to the axis **82** of the reaction assembly.

The reaction plates **42** and **70** form the anchor points for reaction pins **86**, **86′**, which pins correspond to the points P as shown in FIG. **4**. For this purpose, the plates in juxtaposition to each linkage assembly are provided with a pair of parallel apertures **87**, **87′**.

The reaction pins **86** include an inwardly directed bearing portion **88**, a locating shoulder or collar **89**, and a threaded outer end portion **90**. It will be understood that the pins are mounted by insertion through the apertures **87**, **87′** and are locked in position by the pin retainer nuts **91**.

For purposes of clarity, only one pin of each pair of linkages is shown in FIG. **3**.

Short links corresponding to the links S of the diagrammatic view, FIG. **4**, are shown at **92** in FIGS. **1** to **3**. The links **92** are provided with internal outer and inner bores **93**, **94**, the axes of the bores **93**, **94** being parallel, the radius of the bores being such as to intersect and leave therebetween internal divider segments **95**, **96**.

The inner bores **94** of the short links **92** are mounted on the bearing portions or trunnions **88** and the reaction pins **86**, a thrust washer **97** being preferably interposed between the links **92** and the collars **89** of the reaction pins. The link **92** is secured against inward movement relative to the right hand reaction plate **42** by annular retainer member **130**, held in place by machine screws **131**. In similar fashion, the links **92** are secured against movement away from the left hand reaction plate **70** by annular retainer member **132** which is recessed at angularly spaced positions to provide clearance for pivotal movement of the links **92**, the member being secured to the plate **70** by machine screws or like means (not shown).

The long links corresponding to the links L are comprised of a multi-part construction including an inner link component **98**, a transversely extending cross link **99** and a connector sleeve **100**. It will be appreciated from an inspection particularly of FIG. **3** that the length of a cross link **99** is such as to enable both of its end portions **101** and **102** to be utilized in conjunction with a different Scott-Russell linkage.

Hereinafter in the specification and claims, the two Scott-Russell linkages which are secured to the opposite sides of a cross link **99** will be referred to as "tandem linkages." It will be understood that the two linkages forming a tandem operate about coaxial pivot points, to move in displaced planes, as opposed to a "-pair" or "parallel pair" of linkages, which operate in common planes but about parallel displaced axes.

The common axis **103** of the cylindrical ends **101**, **102** of the cross links **99** corresponds with the pivot point C in the diagrammatic view, FIG. **4**. It will be appreciated that the outer bores **93** of a tandem of short links **92** are pivotally mounted on the portions **101** and **102** of the cross link **99**.

The connection between the long link **99** and the stub shafts **75**, **77** and the stub shafts **76**, **78**, respectively, are effected through the use of the inner links **98** previously described. In this connection, each inner link **98** includes a bearing aperture **104**, the apertures **104**, **104** of a tandem pair of inner links **98**, **98** being mounted on the opposed stub shafts **75**, **77**, respectively.

The outer ends **105** of the inner links **98** are provided with semi-circular recesses **106** defined by opposed legs **107**, **108**. A retainer cross bore **109** extends through both legs **107**, **108**. The cross link **99**, inwardly adjacent its end portions **101**, **102**, is provided with reduced diameter portions **110**, **111**. It will be appreciated that the inner links **98** are connected to the cross link **99** by placing the legs **107**, **108** in straddling position of the reduced diameter portions **110**, **111**, respectively. Connector apertures **112**, **113** are formed in the reduced diameter portions, which connector apertures, in the straddling position of the links **98**, are aligned with the cross apertures **109** in the legs **107**, **108**, the parts being maintained in the assembled position by the locking pins **114**, which are inserted through the registering apertures.

As best seen in FIGS. **2** and **3**, the body portion **115** of the cross link **99** defines a hollow cylindrical portion, **116** representing the axis of the cylinder **115**. Connection between the long link and an opposed pair of slide blocks **83** is effected by the tubular connector sleeve **100**. The outer surface of the sleeve **100** fits intimately and rotatably within the cylindrical portions **115** of the cross link **99**. The ends **117**, **118** of the connector sleeve **100** are recessed at **119** and **120**, to provide clearance for pivotal movement of the short links **92**. The ends **117**, **118** of the connector sleeves **100** are received within the semi-cylindrical recessed portions **121**, **121** in the tandem slide blocks **83**. For this purpose, apertures **122** are formed through the sleeves adjacent the ends **117**, **118**, machine screws **123** being passed through the apertures **122** and threadedly connected into complemental tapped bores **124** formed in the slide blocks **83**.

From the foregoing it will be apparent that the long link assembly is connected to the piston for pivoting movement about parallel pivot axes **125**, **126**; that the short links are free to pivot relative to the connector link portion **99** of the long link about the pivot axis **103**; and that the long links are free to pivot relative to the blocks **83** about the pivot axis **116**.

For convenience, and for purposes of improved understanding, the axes **116**, **103** and **125**, corresponding respectively with the pivot points A, C and E, have been applied to FIG. **4**.

From the foregoing, the operation of the apparatus of FIGS. **1** to **3** will be evident.

Where the device is used as a pump, the shaft **20** is driven, thus to rotate the reaction assembly **68**. It will be appreciated, as best seen from FIG. **2**, that the axis of rotation **135** of the block will have been offset from the axis of rotation **82** of the reaction assembly. As is known, the distance between the axes **82** and **135** will determine the displacement of the pump, the greater the distance, the greater the displacement. The rotation of the reaction assembly causes concomitant rotation of the block by reason of the interconnection of the linkages, pistons and reaction assembly previously described.

It is important to note that since torque is transmitted to the reaction ring rather than to the block where the device is used as a pump (and extracted from the reaction ring rather than the block when the device is used as a motor), substantial operating torques are not transferred through the pistons and linkages. It should be noted that the sole transmitted torques through such pistons and linkages are the torques required to overcome friction and rotate the block. This is so because the positions of the pistons within the block are stabilized by reason of the novel linkage.

It will be further appreciated that with continued rotation, the pistons are reciprocated inwardly and outwardly relative to the cylinders, the short links being disposed in parallelism with the long links at two positions during each rotation of the block and the reaction ring, notably at the point of maximum outwardmost movement of the pistons, as represented by the lefthandmost set of links shown in FIG. **2**, and at a position 180° displaced therefrom, representing the radial innermost position of the pistons.

It will be understood that the oscillation of the pistons relative to the cylinders will cause fluid to be sucked into the cylinder chambers during one half of the rotative cycle from one of the chambers **59** or **60**, depending upon the direction of rotation, the fluid being discharged under pressure into the other of the chambers during the radial inward movement of the pistons. In common with other radial piston pumps and motors, it will be appreciated that higher pressures and lower volumes may be developed with a given torque input where the eccentricity is reduced, and vice versa.

The radial pump or motor employing the novel linkage hereinabove described has the unique advantage, as contrasted with any pump or motor heretofore known, of providing a fully stabilized piston (i.e. stabilized against both cocking forces of the piston relative to the cylinder and lateral forces against the cylinder walls), without concomitant drawbacks. Most particularly, the pump-motor of the present invention provides full stabilization without requiring a linear or arcuate sliding movement between the outermost end of a piston and an arcuate or planar track portion.

For instance, in one known type of radial piston pump or motor, the outermost end of the piston is stabilized by being pressed against a flat reaction track forming a portion of a polygonal reaction assembly. It will be appreciated that in such construction the piston is stabilized relative to the cylinder by its engagement against a flat track portion. However, such stabilization is achieved only at the cost of great mechanical losses, since the outermost end of the piston is scanned back

and forth across the flat track portion during each rotation a distance approximating the radial displacement of the piston. Since the outward forces of the piston against the track may amount to many tons, it will be evident that great mechanical losses and wear will result from the noted movement and, by reason of the quantum of forces, unusual and expensive bearings must be interposed between the relatively moving parts. Use of simple but effective hydrostatic bearing principles alone is not feasible or effective.

The advantages of the herein described linkage will be immediately appreciated when contrasted with radial pumps or motors employing conventional annular reaction ring assemblies. In such assemblies, the outermost end of the piston engages against an annular reaction track or ring, resulting in the application of forces between the ring and the piston which are, during the majority of the rotating cycle, directed non-axially of the piston. As will be readily understood, such non-axial forces tend to cock the piston relative to the cylinder bore, resulting in premature wear. Attempts to overcome wear problems by elongating the pistons, thus elongating the contacting cylinder-piston overlap, creates still other problems, such as increase in overall diameter and weight of the pump-motor without concomitant displacement increase, and difficulties in maintaining adequate lubrication in the overlapping areas of the piston and cylinder.

In addition, structures using the conventional annular reaction ring embody the same problems of sliding movements between the piston slipper and the reaction ring discussed in connection with polygonal reaction track pumps and motors, with consequent wear and efficiency losses, etc.

A further solution which has been attempted is exemplified by the patent to Centervall, U.S. Pat. No. 2,001,706 of May 21, 1935. In that construction, attempts have been made to stabilize the piston against cocking by the interposition of a parallelogram linkage between the piston and a reaction ring assembly. While such apparatus does, to a degree, reduce the forces which tend to cock the piston axis and displace it from the cylinder axis, it does not prevent the application of considerable forces, tending to displace the piston from the center line of the cylinder. Moreover, in a device of the Centervall type, operating torque is transmitted through the piston and piston linkages, magnifying the wear problems inhering in the application of piston displacing forces.

In similar fashion, Tobias U.S. Pat. No. 3520,233 tends to combat both cocking and displacing forces but involves manufacturing difficulties which limit the widespread employment of this design.

In accordance with the present invention and for the first time in a radial piston pump or motor assembly, the use of the novel linkage hereinabove set forth enables the production of a pump or motor having lower mechanical losses by a significant margin as contrasted with any such pump or motor heretofore known.

It will be appreciated further that the paired Scott-Russell linkages may be interposed between the piston and the reaction assembly in a plurality of different arrangements while still enjoying the advantages of the present invention.

For purposes of illustration there are shown three modified linkage connection arrangements, namely, those of FIGS. **6–7**, **8–9**, and **10–11**.

The illustrated arrangements are not considered to exhaust the possible orientations of linkage arrangements which may be utilized without departing from the spirit of the present invention which, in its broadest phases, is considered to reside in the use of paired Scott-Russell linkages. Thus, by way of example, while all of the embodiments have illustrated the use of a slide block which extends generally radially of the reaction assembly or the block assembly, it will be appreciated that an arrangement wherein the slide block shifts normal to such radial direction is feasible.

In the device of FIGS. **6** and **7**, **200** represents the reaction assembly having a guideway for controlling each piston, which guideway is defined by the parallel walls **201**, **202**. The slide block is shown at **203**, the block being shiftable reciprocably in the direction of the line **204**. **205** represents the piston. **206** and **207** represent the long links of separate paired Scott-Russell assemblies and **208** and **209** are the short links, respectively, of such assemblies.

The ends of link **206** are connected at **210** and **211** to the piston **205** and the block **203**, respectively. The ends of the long link **207** are connected at **212** and **213** to the piston **205** and the block **203**, respectively.

The short link **208** has one end connected at **214** to the central point of long link **206**, the opposite end **215** of the link **208** being connected at **216** to a fixed pivot point on the reaction assembly **200**. In similar fashion, short link **209** has one end **217** pivotally connected to the central point of long link **209**, the opposite end **218** of the link **209** being pivotally connected at **219** to a pivot point on the reaction assembly.

The effective length of the links **208** and **209** is one half the effective length of the links **206**, **207** and, accordingly, points **210** and **212**, the points of connection to the piston, will be stabilized by reason of the use of such linkage.

It will be recognized that the embodiment of FIGS. **6** and **7** is essentially an inversion of the embodiment of FIGS. **3** to **5**.

In the embodiment of FIGS. **8** and **9**, the piston **220** is provided with an extension portion **221** forming a guideway for an axially shiftable slide block **222**, having a bearing portion enabling the block to be reciprocated in an axial direction only relative to the piston, as indicated by the line **223**.

224 and **225** are paired Scott-Russell linkages having their long links pivotally connected at their upper ends **226**, **227**, respectively, to the slide block **222**. The other ends **228**, **229** are fixed to the reaction assembly. The free ends of the short links of the Scott-Russell assemblies **224**, **225** are fixed at **230**, **231**, respectively, to the piston **220**.

The embodiment of FIGS. **10** and **11** consists essentially of an inversion of the apparatus of FIGS. **8** and **9**, wherein **240** and **241** are the paired Scott-Russell linkages, **242**, **243** are the pivotal points of connection to fixed positions on the reaction assembly,**244** is the slide block, slidably reciprocable on guide surface **245** of the piston **246**. **247** and **248** are the points of connection of the free ends of the short links to the piston **246**.

In each of the diagrammatically illustrated embodiments of FIGS. 6 to 11, it will be observed that the piston is stabilized relative to the cylinder and is reciprocated by the paired Scott-Russell linkages to effect the desired oscillating movement.

Numerous modifications may readily suggest themselves to the skilled worker in the light of the teachings hereof, such modifications to be considered within the scope of the present invention. Accordingly, the present invention is to be broadly construed within the scope of the appended claims.

Having thus described the invention and illustrated its use, what is claimed as new and is desired to be secured by Letters Patent is:

1. In a radial piston pump-motor of the type including a pintle shaft, a cylinder block rotatably mounted on said shaft and having cylinders progressively positioned fluid flow communication with the high and low pressure manifolds of said shaft, piston members reciprocably mounted in sealing relation of said cylinders, and a reaction assembly member rotatable about an axis parallel with but offset from the rotational axis of said block, the improvement which comprises piston operating linkage means interposed between said piston members and said reaction assembly for transmitting forces therebetween, said linkage means each comprising at least one parallel pair of Scott-Russell linkage assemblies, each member of each said pair having a link portion pivotally secured to a piston member, the lines between said pivotal connections to each piston of each pair being at all times perpendicular to the axis of rotation of said block.

2. The device of claim 1 wherein said linkages include a common slide block portion.

3. The device of claim 2 wherein said reaction assembly includes a slideway and said slide block portion is journalled in said slideway for movement toward and away from the axis of rotation of said reaction assembly.

4. The device in accordance with claim 2 and including tandem pairs of parallel Scott-Russell linkages, said pairs being located at opposite sides of a plane extending through the axes of said cylinders.

5. The device of claim 4 wherein said pistons are cup-shaped and outwardly lap said radial outer ends of said cylinders, at least one sealing ring being disposed between the lapping portions of said pistons and cylinders.

6. The device of claim 1 wherein said pistons include guide portions and said Scott-Russell linkages include slide block portions reciprocably mounted on said guide portions for movement axially of said cylinders.

7. The device of claim 2 wherein said Scott-Russell linkages include long links and short links and the radial outermost ends of said long links are fixed to the slide block portion of said linkages, the radial innermost ends of said long links are fixed to said pistons, and the free ends of said short links are pivotally connected to said reaction assembly.

8. The device of claim 7 wherein said slide block portion of said linkages are mounted in guideways formed in said reaction assembly, said guideways cooperating with said block for limiting movement of said block to a direction which is radial of said reaction assembly.

9. The device of claim 8 wherein each said piston is controlled by two pairs of parallel Scott-Russell linkages arranged in tandem to opposite sides of said piston, the points of connection of said pairs to said piston being equally spaced from a plane common with the axes of said cylinders.

10. The device of claim 1 wherein said pump or motor includes a drive shaft connected to said reaction assembly.

11. A hydraulic pump-motor device comprising a pintle shaft, a cylinder block mounted for rotation on said shaft, a plurality of piston members mounted on said block for reciprocal movement radially of said block, said piston members and block defining a plurality of variable displacement chambers, porting means in said block for sequentially connecting said chambers with high and low pressure manifold areas of said pintle as said block rotates about said shaft, a reaction assembly rotatable relative to said shaft about an axis displaced from but parallel to the axis of rotation of said block, Scott-Russell linkage means interposed between each of said pistons and said reaction assembly, said linkage means each including a guide member mounted on said reaction ring for reciprocal movement radially with respect to the axis of rotation of said reaction assembly, a pair of parallel long links having their distal ends pivotally connected respectively to a piston member and a guide member, a pair of parallel short links having their ends pivotally connected respectively midway between the pivots of said long links and to said reaction assembly at points equidistant from the axis of rotation thereof, the effective length of said short links being one half the effective length of said long links.

12. The device of claim 11 wherein said linkage comprises two parallel pairs of said links, said pairs being located in planes parallel to and equally spaced from a plane extending through the axes of said cylinders.

13. A hydraulic pump-motor device comprising a pintle shaft, a cylinder block mounted for rotation on said shaft, a plurality of piston members mounted for reciprocal movement radially of said block, said piston members and block defining a plurality of variable displacement chambers, porting means in said block for sequentially connecting said chambers with high and low pressure manifold areas of said pintle as said block rotates about said shaft, a reaction assembly comprising a spaced pair of reaction plates one to each side of said block, said plates being mounted for rotation about a common axis parallel with and displaced from the axis of said block, said plates each including a plurality of guideways, in number corresponding to the number of said piston means, a plurality of stabilizers having their opposed end portions slidably received in a guideway in both said plates, said stabilizers being carried in said guideways for reciprocal movement radially relative to said common axis, a pair of pivot pins extending from each side of each said piston means, said pins having their axes parallel with said common axis, a Scott-Russell linkage means including a pair of parallel long links to each side of said pistons, said links having their inner ends pivotally connected to said pins, the outer ends of said parallel long links being pivotally connected to said stabilizers, a pair of short parallel links to each side of said piston means, said short links

having their ends pivotally connected respectively midway between the pivots of said long links and to one of said reaction plates, the points of connection of said short links to said plates being equidistant from the axis of rotation of said plates, the effective length of said short links being one half the effective length of said long links.

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