Oct. 23, 1962 H. THOMA 3,059,432

AXIAL PISTON HYDRAULIC UNITS

Filed Jan. 22, 1960 4 Sheets-Sheet 1

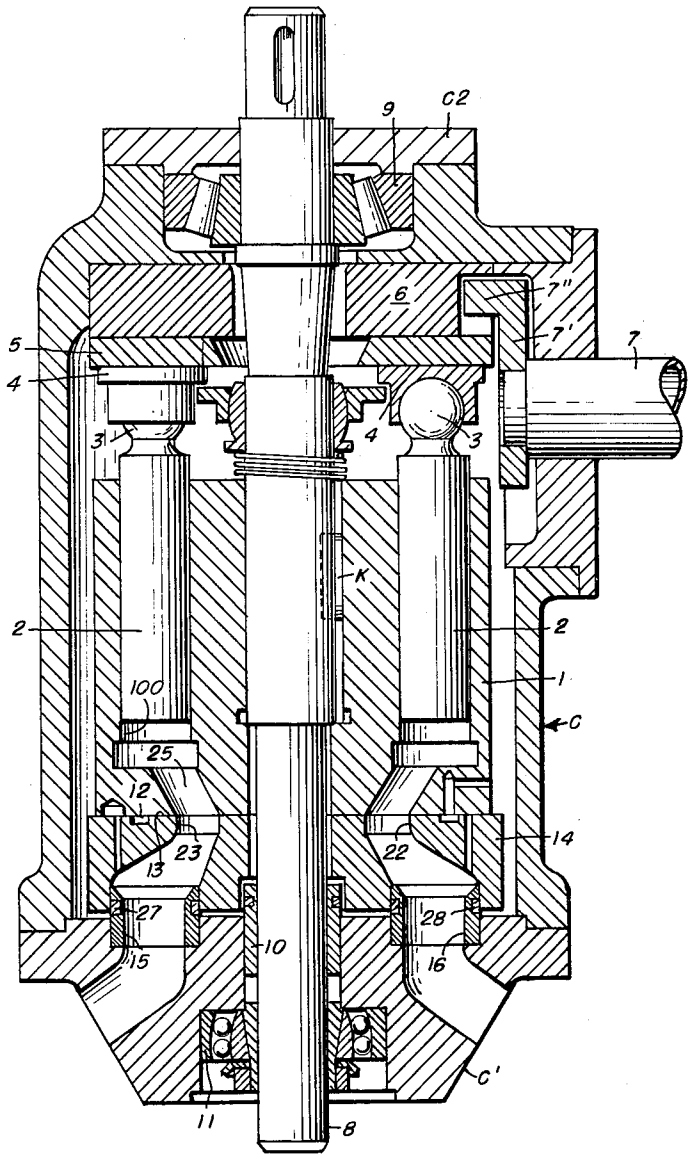

FIG. 1

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AXIAL PISTON HYDRAULIC UNITS

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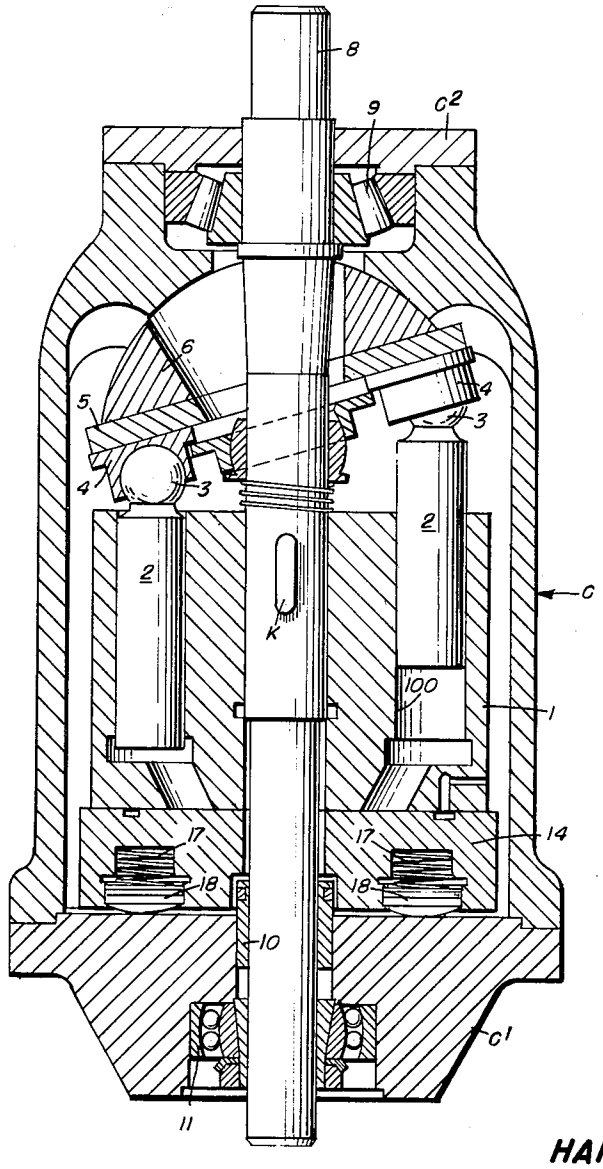
FIG. 2



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AXIAL PISTON HYDRAULIC UNITS

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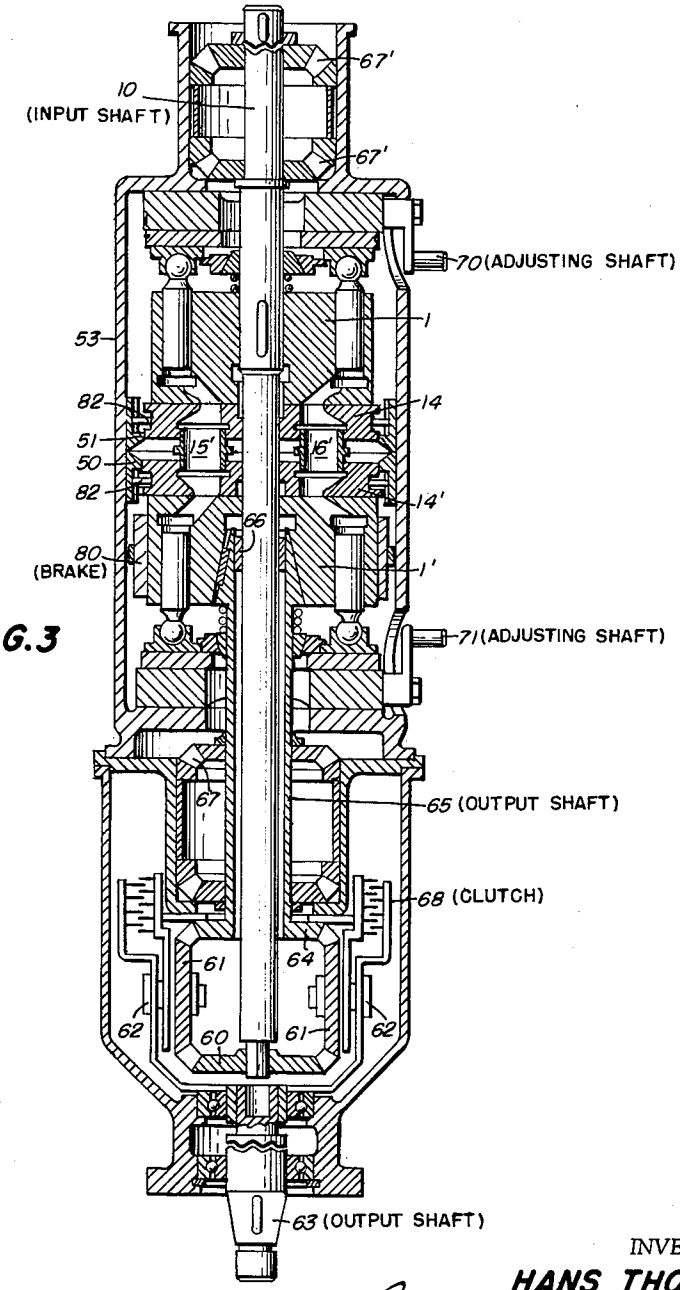

FIG. 3

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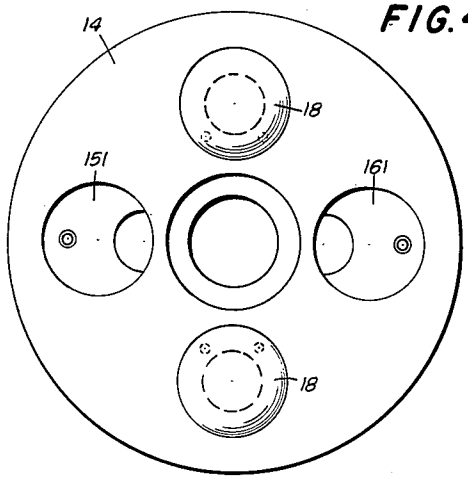
FIG. 4



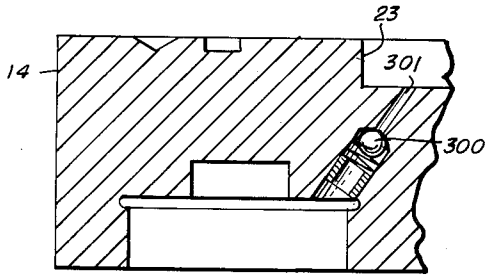


FIG. 5

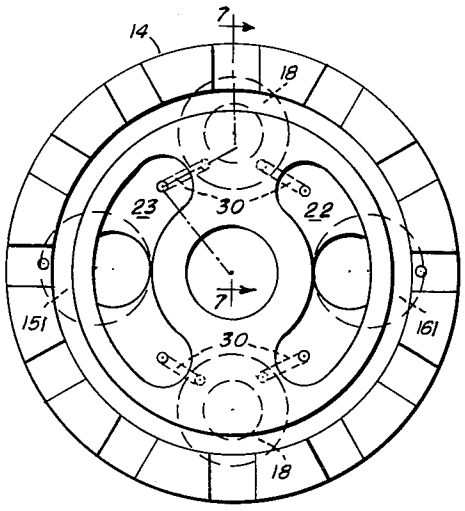


FIG. 6

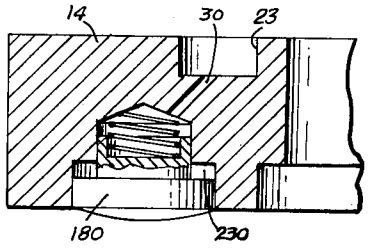


FIG. 7

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Patented Oct. 23, 1962

3,059,432

AXIAL PISTON HYDRAULIC UNITS

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Filed Jan. 22, 1960, Ser. No. 4,138
Claims priority, application Germany Jan. 24, 1959
8 Claims. (Cl. 60—53)

The present invention relates broadly to the art of hydraulic units. More particularly, this invention relates to axial piston hydraulic units of the general type disclosed in German Patent No. 829,553.

The invention therefore specifically relates to certain improvements in hydraulic units of a type which can also be termed swashplate motor or pump units. Such improved units include axially disposed pistons having integral therewith or permanently connected thereto a spherical head which is engaged in a complementary-shaped socket on a slipper that bears against a preferably non-rotatable inclined plane or plate, generally referred to in the art as a swashplate. The lateral forces produced by the pressure of the pistons against the inclined plate are transmitted by the rigid or solid pistons back to the cylinder block and from there to a drive shaft. The fluid flow to and from the axially disposed cylinders is via a non-rotating control or timing plate formed with Generally, the segmentally-shaped inlet and delivery ports are in alignment with the piston accommodating bores or cylinders.

It is, therefore, one object of the present invention to provide an improved structural relationship of such axial piston hydraulic units in which the ports through which fluid flows to and from the cylinders are offset from the pitch circle of the cylinder block toward the axis of rotation thereof so as to thereby substantially reduce leakage and other losses.

It is another object of the invention to provide an improved axial piston hydraulic motor unit in which the non-rotating timing or distribution plate is mounted within the casing in such a manner as to permit slight adjusting movements. The mounting or suspension for such plate transmits forces to the plate to overcome the pressure reaction between the timing plate and the cylinder block due to the surface of the delivery ports. This mounting also produces a certain excess of pressure that urges the timing plate into intimate contact with the cylinder block. This excess pressure acts on the timing plate at least approximately close to its symmetrical axis so as to avoid large tilting moments between the timing plate and the adjacent face of the cylinder block.

It is a further object of this invention to provide a compact hydrostatic transmission in combination with planetary or other gearing in a power splitting relationship in which two axial piston hydraulic units are mounted in coaxial relationship, one of these units including a hollow drive shaft and the drive shaft of the other unit extending through such hollow drive shaft and being operably coupled to the gearing so as to feed power thereto.

It is a further specific object to provide an axial piston hydraulic unit which includes a stiff or rigid drive shaft relationship resulting in a minimum noise level and in which such drive shaft is mounted or suspended at one or both ends in plural bearings capable of transmitting bending moments.

Further and more specific objects of the present invention will be apparent from the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a view partly in elevation and partly in longitudinal cross-section of an axial piston unit of the invention,

FIGURE 2 is a similar view taken at right angles to the relationship of FIGURE 1 and showing the unit of the invention with the parts in a different position,

FIGURE 3 is a view partly in elevation and partly in longitudinal cross-section illustrating the combination of two axial piston units with a gearing and in which the two units and gearing are disposed coaxially in casing means,

FIGURE 4 is a plan view of that face of the timing plate remote from the cylinder block,

FIGURE 5 is a cross-sectional view on an enlarged scale illustrating a part of a timing plate,

FIGURE 6 is a plan view of the face of the timing plate opposite to that shown in FIGURE 4, and

FIGURE 7 is a cross-sectional view taken along line 7—7 of FIGURE 6.

In the drawings, the unit of FIGURES 1 and 2 includes a casing structure C which includes apertured end closures C^1 and C^2 and within which is mounted a cylinder block 1 rigidly keyed by key means K to a drive shaft 8. The cylinder block 1 is provided with a plurality of axially disposed piston accommodating bores or cylinders 100. Within the bores are disposed pistons 2 which have at one end a spherical head 3 that is either integral with each piston or is permanently connected thereto. The spherical heads of the pistons 2 are mounted in complementary-shaped sockets formed in slippers 4 which are in engagement with the inclined plate 5 connected to the substantially semi-cylindrically-shaped member 6. The outer surface of this member is engaged in an arcuate surface at one end of the casing as shown in FIGURE 2. The inclination of the plate 5 can be varied by turning the shaft 7, FIGURE 1. The shaft 7 is an adjusting shaft and carries on its inner end a lever 7′ having a tongue 7″ that fits in a bore in the member 6 so that when shaft 7 is turned the member 6 is displaced to vary the inclination of plate 5. Bearings 9, 10 and 11 rigidly support the drive shaft within the casing.

The inlet and delivery flow of liquid to the cylinders is via a non-rotating control or timing plate 14 having segmentally-shaped admission and delivery openings 22 and 23 which communicate with ports 25 in the cylinder block that lead fluid to and from the respective cylinders, see FIGURE 6. As is clear from FIGURES 1 and 2 the upper ends of the admission and delivery ports, that is, the openings at the surface of the timing plate and the adjacent ends of the ports in the cylinder block are offset from the pitch circle of the cylinders toward the axis of rotation or the axis of symmetry of the unit. This offsetting provides important advantages, namely, it has a tendency to reduce leakage and pressure losses because the cross-sectional area of the segmental admission and delivery ports and the fluid ports in the cylinder block can be made larger for a given total surface area under pressure. While this relationship might lead to the disadvantage that considerable tilting moments are generated in the cylinder block, because the reactions of the piston forces are no longer in alignment with the pressure reactions through the cylinder ports, this advantage is overcome by rigidly keying the cylinder block to the drive shaft so as to in effect carry away this tilting moment. The other load the drive shaft has to carry is derived from the side or lateral forces generated by the pistons bearing against the inclined plate 5. Both of these loads set up bending moments in the drive shaft but the bending moment on the drive shaft due to the tilting moment on the cylinder block is perpendicular to the bending moment induced in the drive shaft by the lateral forces generated by the pistons. Therefore, the additional bending moment due to tilting forces does not substantially increase the total bending load on the drive shaft,

but mainly displaces its resultant direction which has no effect on the stability and longevity of the drive shaft and on the bearings that mount the same.

In order to maintain the timing plate **14** in tight contact with the end face of the cylinder block, it is adjustably mounted within the casing and the fluid or oil is admitted to or delivered from the timing plate via bushings **15** and **16** mounted in openings **151**, **161**, FIGURE 4 which can be sealed against leakage by sealing rings **27** and **28**, FIGURE 1. Since the bushings should not impair the adjustability of the timing plate relative to the casing, they are preferably made with short cylindrical or spherical seats or are of such thin wall thickness as to be elastically deformable.

Since it is not always practical to arrange the bushings **15** and **16** in alignment with the segmentally-shaped admission and delivery ports and preferably it is better to locate them radially outwards of the control openings of these ports, the invention provides two balancing pistons **18** preferably located closer to the axis than the bushings. Further, the balancing pistons are preferably offset longitudinally from the bushings. These balancing pistons are provided with pre-loading springs **17** and are connected by conduits **30**, FIGURES 6 and 7, to the inlet and delivery ports **22** and **23**. In FIGURE 7 is shown the provision of annular chamber **230** incorporated around a balancing piston **180**. In FIGURE 5 is illustrated a suitable check valve **300** provided in the conduit **301** connecting the space that accommodates the balancing piston with the delivery port **23**.

By a suitable location and dimensioning of the bushings **15** and **16** and of the balancing pistons **18** the reaction between the casing and the timing plate can be controlled so as to overcome the reaction forces due to the pressure field between the timing plate and the end face of the cylinder block and to provide an excess force acting approximately centrally of the timing plate to urge it into contact with the cylinder block. Since it will be generally necessary to provide a certain amount of excess force on the timing plate acting in a direction toward the cylinder block in order to, with certainty, overcome pulsating piston forces, it is preferable to locate a pressure fed axial bearing **12** and **13** between the timing plate and the cylinder block. The structure and nature of this relationship is more clearly shown in my prior U.S. Patent No. 2,916,334, dated December 8, 1959.

FIGURE 3 shows the preferred embodiment of the application of two axial piston units of the invention in a hydrostatic transmission having a split power arrangement. Thus, the relationship includes a two-part casing means mounted in end to end relationship so that, as viewed in FIGURE 3, the upper casing part accommodates two coaxially arranged axial piston units whereas the lower casing part accommodates a gearing relationship and an output shaft. Thus, the two axial piston units include cylinder blocks **1**, **1'** arranged coaxially with the associated timing plates **14**, **14'** arranged adjacent to one another so there is only a common set of bushings **15'**, **16'** which transmit the oil directly from one timing plate to the other. Both timing plates are mounted for slight adjustable movement relative to the ring members **50**, **51** on the interior of the casing part **53**, while pins or bolts **81** and **82** prevent rotation of these timing plates.

The input shaft **10** that is keyed to the cylinder block **1** is elongated and has a squared end fitting in a similarly shaped aperture in a bevel gear **60** of a known differential gear relationship. The drive shaft **65** that is keyed to cylinder block **1'** is hollow and surrounds input shaft **10**. A bevel gear **64** is formed on or fixed to the end of hollow drive shaft **65** and bevel gears **61** mounted in a cage **62** are in mesh with gears **60**, **64** and the cage is connected to the output shaft **63**. This relationship operates in a known manner to provide a split power arrangement where a part of the power is transmitted mechanically, another part hydraulically and both parts combined

in the differential gear which feeds the power to the output shaft. The arrangement further includes a clutch means **68** which when operated, clutches the hollow shaft **65** to the output shaft **63**, thereby introducing a direct mechanical transmission ratio of 1 to 1. This relationship is of advantage, particularly in some vehicular applications of the invention. The shaft **10** is connected to the engine of the vehicle by any suitable means known in the art.

The adjustability of the angle of inclination of the swashplates against which the slippers bear, and thus the variation in the stroke of the pistons can be controlled by turning shafts **70**, **71**.

Further, in order to provide for high flexural stiffness in shafts **10** and **65** and thus minimum flexural deformation, both of these shafts are mounted in a pair of conical roller bearings. The bearings for shaft **65** are shown at **67**, and shaft **10** is mounted in similarly shaped bearings **67'** shown at the upper part of FIGURE 3. Each pair of roller bearings provides a mounting or suspension which is capable of absorbing bending moments.

The transmission further includes a brake **80** of any suitable type such as a band brake. Ordinarily this brake is loose or not applied so as to permit proper operation of the transmission. However, in the event of lack of oil or other disturbance in the transmission, the application of the brake will effect the connection between the input and output shafts. Thus it is possible in the case of an emergency to move the car by running the engine or in the event of starter failure to permit pushing or towing of the car in order to turn over the engine.

The clutch **68** in FIGURE 3 can establish a direct drive and permit bypassing of the transmission and can also avoid losses due to oil pressure or circulation problems upon suitable adjustment of the piston strokes in the pump and motor, respectively. Thus in FIGURE 3 the unit including cylinder block **1** is a primary unit and operates as an hydraulic pump, being connected by input shaft **10** to a prime mover such as an internal combustion engine in a vehicle or an electric motor in some other application. The unit including the connecting block **1'** is a secondary unit and functions as an hydraulic motor. The piston strokes of both units can be varied by turning the adjusting shafts **70** and **71**.

The clutch or coupling **68** may be operated either mechanically or by means of oil pressure and arranged to connect the input and output shafts directly or indirectly using the split power transmission or gearing shown in FIGURE 3.

What is claimed is:

1. An axial piston hydraulic unit including a casing, a rotatable cylinder block within the casing, said cylinder block having a plurality of piston-accommodating bores therein, a piston reciprocably disposed in each bore and including an exposed outer end, a rotatable shaft, means rigidly connecting said shaft to the cylinder block, a swashplate cooperable with the exposed outer ends of said pistons, means for disposing said swashplate at an angle to the axis of said shaft for translating rotary motion of said shaft into reciprocable movements of the pistons and vice versa, said cylinder block having an end face constituting a distribution end, ports communicating with said end face and with said bores, a control plate adjacent said end face of the cylinder block, said control plate having segmentally-shaped fluid admission and delivery ports therein terminating in the face of the control plate adjacent the said end face of the cylinder block, means mounting the control plate in the casing for slight adjusting movement relative to the casing and cylinder block so as to maintain tight contact between the adjacent faces of the cylinder block and control plate, the adjacent communicating ends of the ports in the cylinder block and the admission and delivery ports

being offset from the pitch circle of said bores in a direction toward the axis of rotation of the cylinder block and the tilting moments acting on the cylinder block being absorbed by said shaft.

2. An axial piston hydraulic unit as claimed in claim 1 in which means are operatively associated with the control plate for transmitting forces between the control plate and the casing comprising balancing pistons mounted within the control plate and means for feeding oil thereto from at least one of said admission and said delivery ports so as to equalize pressure reactions between the cylinder block and control plate.

3. An axial piston hydraulic unit as claimed in claim 1 and plural bearing means for at least one end of said shaft for mounting such a shaft in a manner capable of absorbing the bending moments.

4. An hydraulic transmission including a casing, two axial piston hydraulic units within the casing and constituting primary and secondary units respectively, said primary unit constituting an hydraulic pump and including a shaft adapted for connection to a prime mover and constituting the input shaft of the transmission, said input shaft being elongated to provide an extension, said secondary unit constituting an oil motor and including a hollow shaft surrounding the extension of the input shaft and constituting an output shaft, said primary unit including a rotatable cylinder block having a plurality of piston-accommodating bores therein, a piston reciprocably disposed in each bore and including an exposed outer end, means rigidly connecting the cylinder block to said input shaft, a swashplate for cooperation with the outer ends of the pistons, means for disposing said swashplate at an angle to the axis of said input shaft for translating rotary motion of the input shaft into reciprocal movements of the pistons and vice versa, said cylinder block having an end face constituting a distribution end, said block further having ports therein communicating between said end face and said piston-accommodating bores, a control plate adjacent said end face of the cylinder block, said control plate having segmentally shaped fluid admission and delivery ports therein terminating in the face of the control plate adjacent said end face of the cylinder block, means mounting said control plate in the casing for slight adjusting movement relative to the casing and cylinder block so as to maintain tight contact between the adjacent faces of the cylinder block and control plate, the adjacent communicating ends of the ports in the cylinder block and the admission and delivery ports being offset from the pitch circle of the piston-accommodating bores in a direction toward the axis of rotation of the cylinder block and the tilting moment that acts on the cylinder block due to this offset being absorbed by said input shaft, the

secondary unit of said transmission comprising a similar cylinder block, means rigidly connecting said last-mentioned cylinder block to said hollow shaft, said second cylinder block having piston-accommodating bores therein, pistons in said bores terminating in exposed outer ends projecting from the face of said second cylinder block remote from said first cylinder block, a second swashplate for cooperation with the exposed ends of the pistons in the second cylinder block, means for disposing said second swashplate at an angle to the axis of said hollow shaft for translating reciprocal movements of the pistons into rotary motion of the hollow shaft and vice versa, said second cylinder block having ports therein providing communication between the piston-accommodating bores of said second block and the end face of such second block adjacent the first block, a second control plate within the casing similar to the first control plate and having similarly arranged admission and delivery ports therein, means mounting said second control plate coaxially with and adjacent to the first-mentioned control plate for slight adjusting movement between the respective control plates, the casing and said second cylinder block and the adjacent communicating ends of the ports in the second cylinder block and the admission and delivery ports in the second control plate likewise being offset from the pitch circle of the piston-accommodating bores in the second cylinder block toward the axis of rotation of such second cylinder block.

5. The combination as claimed in claim 4 and further including a split power gearing arrangement including components connected to the extension of the input shaft of the primary unit and to the hollow shaft of the secondary unit, and a third shaft extending from the casing and constituting an output shaft for the transmission including the split power gearing arrangement.

6. The combination as claimed in claim 4 and further including a plurality of bearings journalling said hollow shaft and said bearings being capable of absorbing bending moments.

7. The combination as claimed in claim 4 and further including a brake means operably related with the secondary unit.

8. The combination as claimed in claim 4 and further including a clutch means operably related between the input and output shafts of the transmission.

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