May 26, 1953 T. MÜLLER 2,639,586

ROTARY PUMP AND MOTOR HYDRAULIC TRANSMISSION

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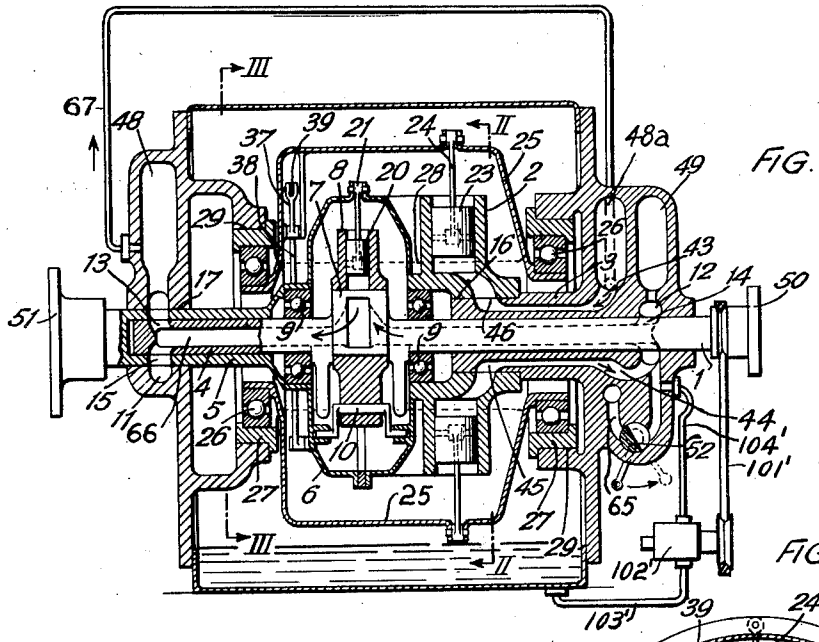


FIG. 1

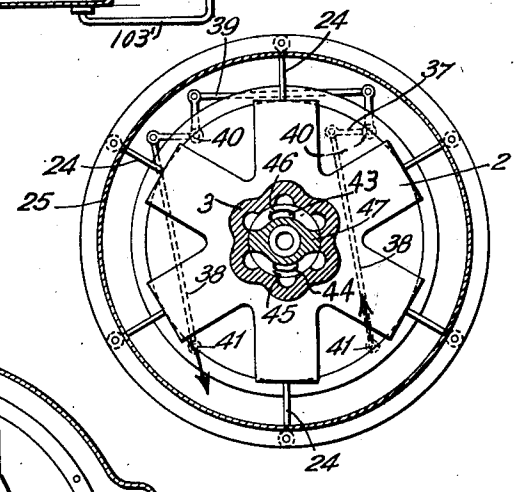
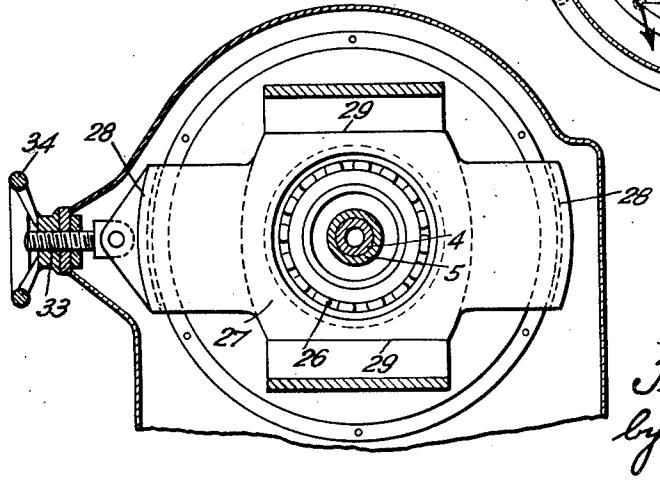


FIG. 3

FIG. 2



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FIG. 4

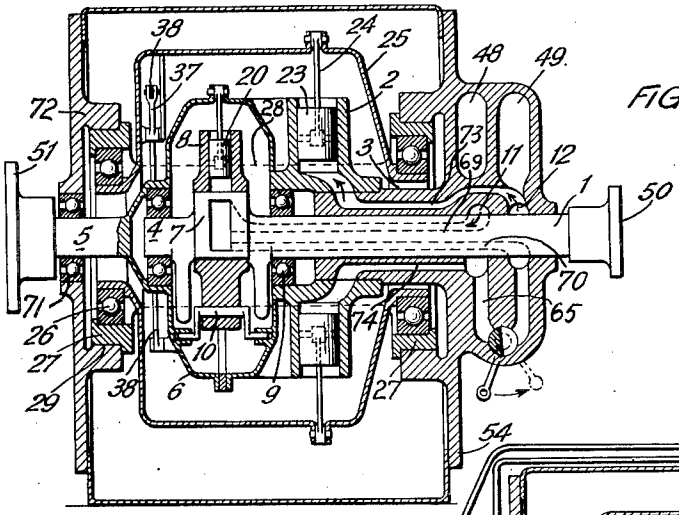


FIG. 5

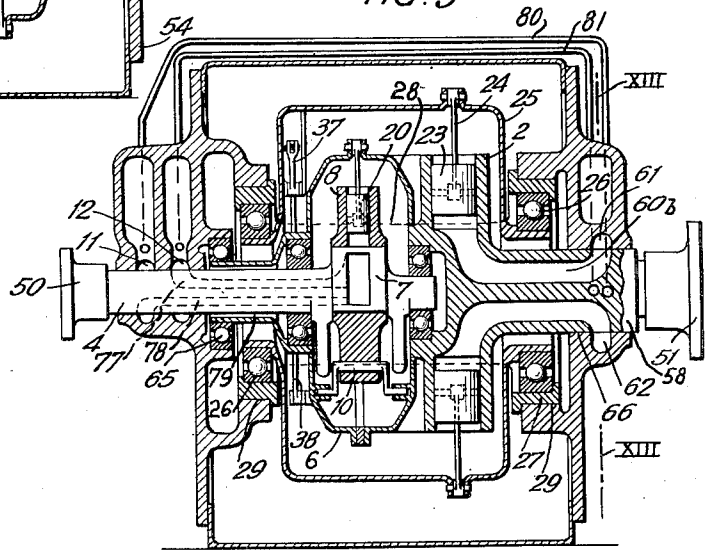
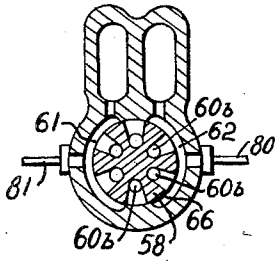


FIG. 13



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ROTARY PUMP AND MOTOR HYDRAULIC TRANSMISSION

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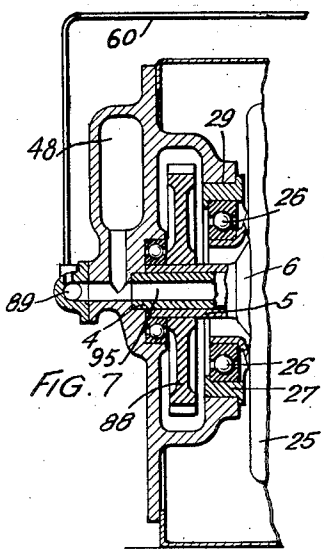


FIG. 7

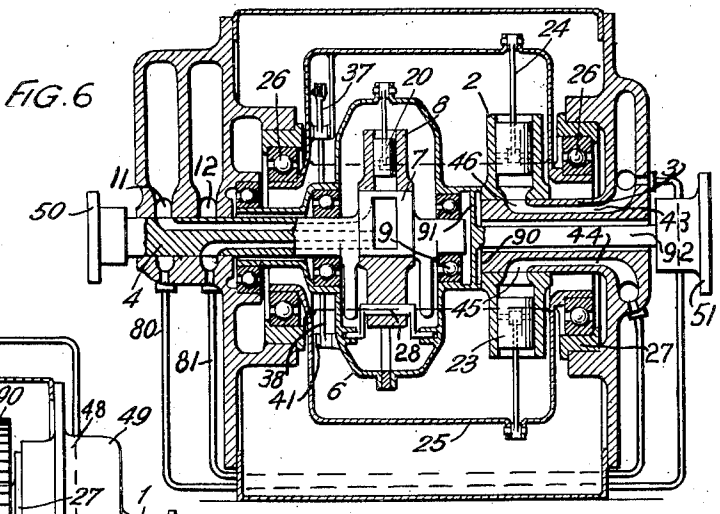
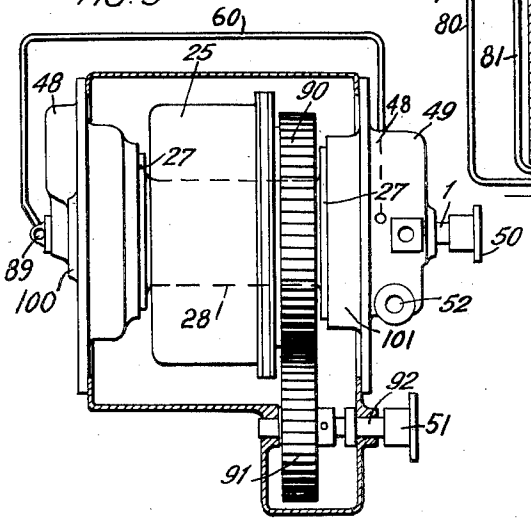


FIG. 6

FIG. 9



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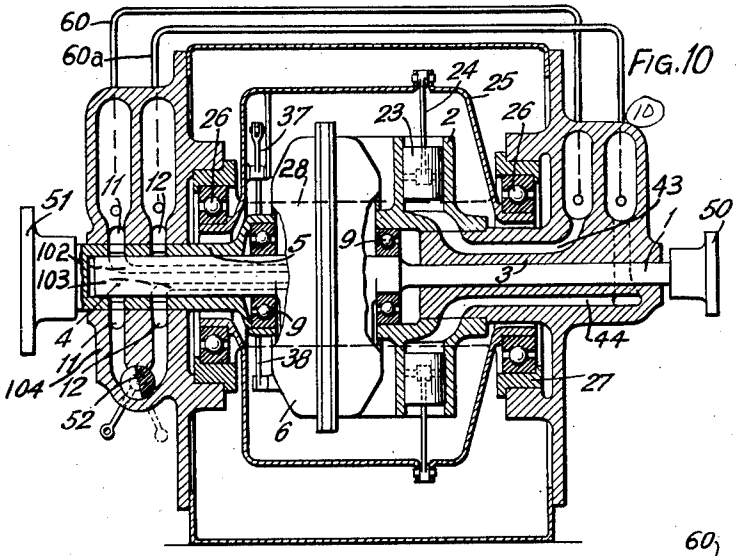


FIG.10

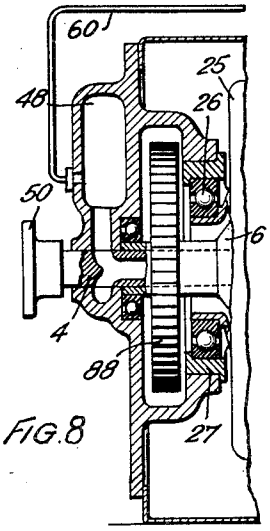


FIG.8

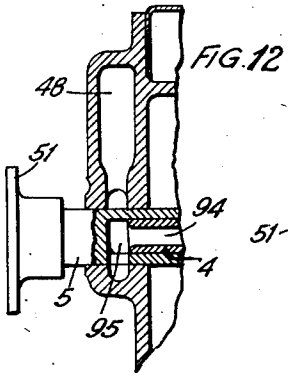


FIG.12

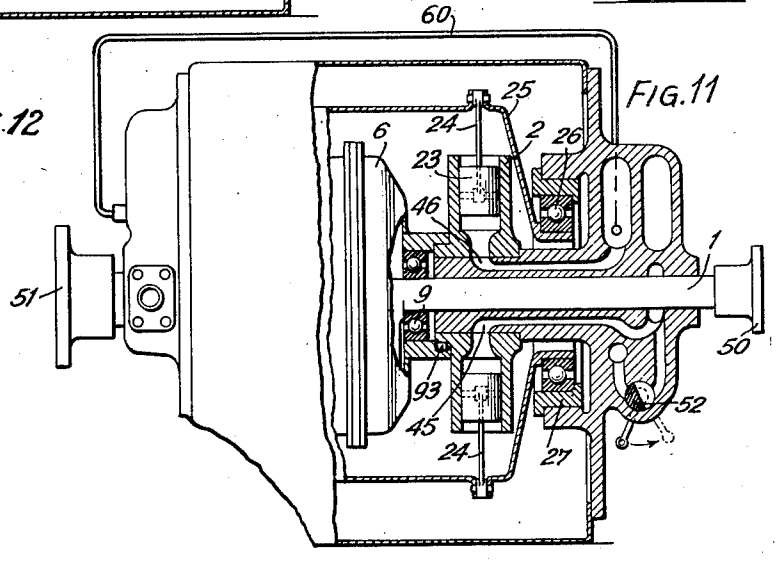


FIG.11

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Patented May 26, 1953

2,639,586

UNITED STATES PATENT OFFICE

2,639,586

ROTARY PUMP AND MOTOR HYDRAULIC TRANSMISSION

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Application August 29, 1947, Serial No. 771,316
In Switzerland May 15, 1942

Section 1, Public Law 690, August 8, 1946
Patent expires May 15, 1962

5 Claims. (Cl. 60—53)

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The present invention relates to hydraulic transmissions of the type comprising a pump unit including a pump cylinder block and a motor unit including a motor cylinder block, in which transmission not only the torque of the motor unit acts upon the driven or output shaft, but also the torque transmitted from the driving motor to the pump unit, since both the pump unit rotor and the pump cylinder block are connected for rotation, one with the driving shaft and the other with the driven shaft. By adjusting the piston stroke of the motor unit to zero, it is possible to check the delivery of the pump unit in transmissions of this type, so that the shaft and the casing of the pump unit, and accordingly the input shaft and the output shaft of the transmission are obliged to rotate one with the other and the transmission operates as a coupling.

The invention further relates to that type of hydraulic transmissions in which the pump unit and the motor unit are each formed as a radial cylinder engine having a star-shaped cylinder block and a revolving casing surrounding the cylinder block and coupled for rotation therewith, both units being controlled by centrally disposed bored shafts provided with control ducts, and in which the radial motor cylinder block is carried by a fixed hub member of the stationary casing of the transmission.

In hydraulic transmissions having a control device of the above type it has already been proposed to obtain a particularly compact construction by uniting the radial cylinder blocks of the pump unit and the motor unit to form a single structure, the top side of the pump cylinders being disposed radially outside, and the top side of the motor cylinders radially inside, while the connecting rods of the motor cylinders are pivotally connected to a rotatable casing surrounding the cylinders. However, this irregular distribution of the pump cylinders and the motor cylinders disposed in the same plane, results in irregular delivery of liquid and operation by shocks, of both the pump and the hydraulic motor; moreover, the cylinders have large dead spaces and the roller bearings of the casing of the motor unit have such large diameters that their practical execution is questionable.

It is an object of the present invention to provide a hydraulic transmission which avoids the mentioned inconveniences, without renouncing a compact, space-saving arrangement.

Other objects and advantages of this invention will appear from the following detailed description in which reference is made to the accompanying drawings showing by way of example several embodiments of the invention in simplified, diagrammatic representation.

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Fig. 1 shows a transmission according to the invention in longitudinal section.

Fig. 2 is a section along the line II—II of Fig. 1.

Fig. 3 is a section along the line III—III of Fig. 1.

Fig. 4 shows in longitudinal section a transmission according to a second constructional example.

Fig. 5 shows a further modified transmission in longitudinal section.

Fig. 6 shows a fourth constructional example of a transmission in longitudinal section.

Figs. 7 and 8 each show a fragmentary longitudinal section of a further modification.

Fig. 9 is a view in elevation, partly drawn in section, of a further modified transmission.

Fig. 10 is a longitudinal section of a further constructional example of the transmission.

Fig. 11 is a fragmentary sectional view of a further modification.

Fig. 12 is a fragmentary sectional view of a modification of a detail.

Fig. 13 is a transverse section along the line XIII—XIII of Fig. 5.

Referring to Fig. 1, the pump unit includes a hollow driving or input shaft 1 journalled in a hollow hub member 3 of the stationary casing and formed with an integral flange 50 for connection to a driving engine. Within the stationary casing the shaft 1 carries an eccentric rotor 7 on which is journalled the pump cylinder block 8. The shaft 4 forms an extension of shaft 1 beyond the rotor 7 and is journalled in a bore of the driven or output shaft 5 of the transmission. The pump rotor 7 and the cylinder block 8 are enclosed within a pump casing 6 to which the output shaft 5 is rigidly secured and to which the cylinder block 8 is connected by crank means 10 for limited relative movement with respect to the casing 6 but for rotation therewith. The pump casing 6 is supported by bearing means 9 on shaft members 1 and 4 on each side of rotor 7. Shaft members 1 and 4 are bored to provide fluid conduits leading to and from the pump unit.

The motor cylinder block 2 of the motor unit is journalled on hub member 3 at 16. This cylinder block and the pump casing 6 are rigidly connected and disposed side by side in close proximity to each other. The output shaft 5 connected to pump casing 6 is journalled in the stationary casing at 17. The entire pump unit and

the motor cylinder block 2 are enclosed in a motor casing 25 which is journalled by bearing means 26 in slides 27 carried by hub members at opposite ends of the stationary casing or housing. The motor casing 25 is rotated along with motor cylinder block 2 and pump casing 6 by linkage means 37, 38 and 39 which serve to connect motor casing 25 to pump casing 6, as best shown in Fig. 3. The bearing means 26 with the slides 27 are slidably mounted in the hub members of the stationary casing as best shown at 29 in Fig. 2, whereby the fluid capacity of the motor unit may be varied by moving the motor casing 25 transversely to the axis of rotation of the transmission by means of screw spindle 33 and hand wheel 34. The pump cylinder block 8 carries pump pistons 20 within its radial cylinder bores, these pistons being pivotally connected to pump casing 6 by piston rods 21. Similarly, the motor cylinder block 2 is provided with radial cylinder bores which carry motor pistons 23 pivotally fastened to the motor casing 25 by piston rods 24.

The hub member 3 is provided with motor fluid inlet passage 43, 46 and motor fluid outlet passage 44, 45 which communicate at their inner ends with the cylinder bores of motor cylinder block 2. The two passages are separated by a web 47 (Fig. 3). The motor outlet passage 44, at its outer end, communicates with the pump inlet passage 14 in shaft 1 and with a make-up line 104' leading from a make-up pump 102'. The motor inlet passage 43, at its outer end, communicates with a manifold 48a which in turn is connected to manifold 48 at the opposite end of the stationary casing by means of pipe line 67. The annular duct 11 of manifold 48 receives fluid discharged from the pump unit by way of pump outlet passage 66 and port 13 in shaft 4, and port 15 in output shaft 5. The manifolds 48, 48a and 49, which latter is connected to the annular duct 12, damp the delivery shocks of the pump and the motor.

The manner of operation of transmissions of the described type is known. When the flange 50 is driven, for example by an electric motor, the make-up pump 102' driven by the shaft 1, fills all conduits which are traversed by liquid, and the pump unit starts to pump. When now the motor unit is adjusted to a stroke equal to zero, this unit absorbs no liquid, and the pump casing 6 to which the output shaft 5 and flange 51 are rigidly connected, runs at the same speed as the input flange 50. The torque of the shaft 1 is then transmitted to the pump casing and from there to the output flange 51 (direct drive, operation as coupling). When the axis of rotation of the motor casing 25 is positioned eccentrically by means of the hand wheel 34, the motor cylinders absorb a certain amount of liquid, and the pump casing 6 and accordingly the flange 51 run more slowly than the input flange 50. Since the eccentricity and therefore also the liquid absorption capacity of the motor unit is limited, a certain minimum velocity of the output shaft 51 can be obtained at maximum eccentricity of the axis of rotation of the casing 25, this minimum velocity being for example equal to ¼ of the number of revolutions of the input shaft. During such operation, the torque of the input shaft 1, like during direct drive, is transmitted to the pump casing 6, but this casing still receives a supplementary torque resulting from the cylinder block 2 working as hydraulic motor. When a still smaller speed than the mentioned minimum speed of the output shaft 51 is required, a by-pass valve 52 is opened, which causes the surplus of the pump delivery from manifold 48a to directly return by passage 65 from the delivery conduit to the suction conduit. A further increase of the torque at the flange 51 is not obtained in this case.

By suitably adjusting the eccentricity of casing 25 it is possible to also obtain a greater speed than direct drive or to obtain a reverse drive. If the axis of rotation of the casing 25 is displaced by means of the hand wheel 34 out of its middle position in the opposite direction to that required for reducing the speed of output shaft 5, the torque exerted by the hydraulic motor on the casing no longer acts in the same direction as the torque of the driving shaft but in the opposite direction. The output shaft 5 thereby receives a torque which is smaller than the driving torque at flange 50 and rotates faster than the driving shaft. Since the pump casing 6 with cylinder block 8, therefore, rotates at higher speed than the input shaft 1, and since the pump outlet 66 in shaft 4 is subjected to high pressure (as at slow speed) as the torque driving the flange 50 still has the same direction as at slow or direct speed, pressure-liquid has to be fed to the pump cylinders so that the direction of flow in pipe line 67 is reversed. In such case, the pump unit actually operates as liquid-motor and is supplied with the required pressure-liquid from the motor unit 2, 25 which, therefore, operates as pump. The motor unit 2, 23, 25 works then as a pump and the pump unit 6, 7, 8 as a motor. If the axis of rotation of the casing 25 is displaced so far out of its middle position in the said direction that the counter torque of the motor unit exceeds the torque of the pump unit a reverse drive is obtained.

When inversely the flange 51 is driven for example by an electric motor running at constant speed, then the transmission operates also as coupling upon the stroke of the motor unit being adjusted to zero. When the motor unit i. e. its casing 25 is adjusted somewhat eccentrically, the pumps cylinder block 8 can operate as pump and delivers pressure fluid to the motor unit, the shaft 1 being capable of turning more slowly than the flange 51. Upon a certain eccentricity of the motor casing, which is, however, only a fraction of the maximum eccentricity mentioned above, it is possible to cause the then driven shaft 1 to stop without requiring to open the by-pass valve 52. A further increase of the eccentricity in the same direction results in reverse speed, whereby pump unit and motor unit exchange their functions as a pump and motor. When the pressure of the working fluid remains constant, a constant torque is obtained at the driven shaft 1 at all speeds of rotation of the driven shaft when the transmission operates as mentioned above, the speed of rotation of this shaft being capable of variation from a negative value to zero and to that of the then driving shaft 5.

It is, however, also possible to drive the flange 51 with variable speed, and the transmission in this case is adapted to produce a constant speed of the flange 50 by appropriate adjustment of the motor unit.

The construction of the modified transmission represented in Fig. 4 differs from that according to Fig. 1 in that the pump inlet passage as well as the discharge passage are formed by bores 69 and 70 in the input shaft 1 extending through the stationary hub member 3 and driven by an engine shaft which will be connected to flange 50. Accordingly, both annular ducts 11, 12 are pro-

vided in the stationary hub member 3. The shaft extension 4 and output shaft 5 do not contain any fluid ducts. Only one end cover 54 of the stationary casing needs to be provided with fluid ducts and with two manifolds 48 and 49; external conduits for the working fluid can be omitted.

The shaft 5 is journalled by means of a ball bearing 71 in the cover 72 of the transmission casing. All the remaining parts of this transmission agree with that shown in Figs. 1–3. The mode of operation also is substantially the same as that of the example shown in Figs. 1–3. Oil is fed to the pump cylinder-block 8 through duct 69, flows out of the pump through duct 70 in driving shaft 1, arrives in the annular chamber 12 whence it flows through inlet passage 73 into the motor cylinder-block 2 and drives the motor unit. The oil then flows from block 2 through outlet passage 74 into the annular duct 11, whence it is recycled through duct 69. The speed of output shaft 5 is adjusted by displacing slides 27, interconnected by the bracket 28, by means of the handwheel 34 (Fig. 2). The mode of operation is the same as that of the transmission shown in Figs. 1–3, with the exception of the disposition of the fluid passages, as just described.

According to Figs. 5 and 13 the pump casing 6, the motor cylinder block 2 and the output shaft 58 form a single rigid body journalled at opposite ends of the stationary housing in ball bearing 65 and at 66. In this case the motor cylinder spaces are extended to form ducts 60*b* in the driven shaft 58 and are controlled by the semi-annular ducts 61 and 62 extending each over one half of the circumference of the shaft 58 and communicating with the pressure and the suction space, respectively, of the pump. The input flange 50 is provided on the pump shaft 4 which contains suction and delivery conduits 77 and 78 for the pump. Conduit 77 is connected by annular duct 12 and pipe line 81 to annular duct 61. Conduit 78 is connected by annular duct 11 and pipe line 80 to annular duct 62. The pump cylinder-block 8 co-operates with pump casing 6 and pump rotor 7 in like manner as in the arrangement shown in Fig. 1, with the exception of the oil-flow through the bores of the input shaft 4. Also the motor cylinder block 2 co-operates with the pistons 23, piston rods 24 and motor-casing 25 in the same manner as in Fig. 1. The slides 27 and bearing means 26 also are displaced in like manner as in Fig. 1. In this construction the torque of the input shaft 4 is transmitted by the pump pistons to the pump casing 6 and is increased by a supplementary torque arising from the star-shaped cylinder block 2 of the motor unit in accordance with the adjusted eccentricity of the motor casing, both torques together being transmitted by the shaft 58 to the output flange 51. The operation accordingly corresponds in principle to that of the example of Figs. 1 to 4.

In the transmission according to Fig. 6, control of the motor cylinder block 2 is effected by means of the stationary hub member 3 carrying this cylinder block. The hub member is provided with fluid inlet passage 43, 46 and with fluid outlet passage 44, 45. Further, the pump casing 6 and motor cylinder-block 2 together are fixed, intermediate the inner end 90 of hub member 3 and the adjacent bearing 9, to the driven shaft 92 by the flange 91. The arrangement and co-operation of the motor cylinder-block 2 with the piston 23 and motor-casing 25, as well as of the linkage means 37—41, are identical with those in the example shown in Fig. 5. The annular ducts 11 and 12, connected to the inlet and discharge of

the pump cylinders, are connected by pipe lines 80 and 81, respectively to the inlet and outlet passages 43 and 44, respectively, of the hub member 3.

As may be seen from Fig. 7 the transmission similar to that of Fig. 1 can deliver the torque by the intermediary of a gearwheel 88 instead of by the flange 51, this wheel 88 being fixed on the extension output shaft 5 connected with the pump casing 6. The bore 95 in the shaft end 4 is connected by port to 89 to pipe line 60. The mode of operation of the hydraulic portion of the transmission is the same as in the case of Fig. 1.

A further modification of the transmission according to Fig. 1 is shown in part in Fig. 8, in which the input flange 50, instead of being provided on the shaft end 1 in Fig. 1, is secured to the shaft end 4. Instead of flange 51 the gearwheel 88 is secured to the output shaft connected to the pump casing 6.

In Fig. 9 a modification of the transmission according to Fig. 1 is shown in which a gear crown 90 is provided on the motor casing 25, and made to mesh with a gearwheel 91 secured to an intermediary shaft 92 carrying the flange 51, the direction in which slide 27, 28 carrying the casing 25 is displaced being at right angles to the line intersecting the centres of the gear crown and gearwheel. The remaining parts housed in casing 25 and in the two stationary hub members 100 and 101 are the same as those shown in section in Fig. 1, and the mechanism for displacing of casing 25 in the same as shown in Fig. 2. The hub member 100 with manifold 48 and its connection to pipe line 60 is constructed in like manner as the identical parts in Fig. 7. The flange 50 of input shaft 1 is driven by an electric motor for example, as in the case of Fig. 1. The torque of shaft 1 is transmitted to the motor unit in like manner as in Fig. 1, i. e. the pump casing within motor casing 25 is connected by linkage means to casing 25 and this latter is connected by gearwheels 90, 91 to the driven shaft 92. The additional torque arising in the motor unit also is transmitted through the said gearwheels to the shaft 92.

In a modification of the transmission illustrated in Fig. 10 the input shaft 1 is not bored. The fluid inlet and outlet passages 102 and 103 to and from the pump cylinders are provided in the shaft portion 4. These passages communicate by ports in shaft 5 with annular ducts 11 and 12, respectively, in the stationary housing member 104. These ducts communicate through pipe lines 60 and 60*a*, respectively, with inlet passage 43 and outlet passage 44, respectively, connected at their inner ends with the cylinder bores of the motor cylinder block 2. Valve 52 for directly interconnecting the inlet and outlet ducts of the transmission is provided in the housing portion 104. This disposition permits the diameter of the shaft 1 to be made smaller than in Fig. 1 and accordingly to reduce the diameter of the portion of the hub member 3 on which the motor cylinder block 2 is mounted. Apart from the slightly different arrangement of the fluid passages, this modification operates in exactly the same manner as the transmission shown in Fig. 1.

When in a transmission according to Fig. 1 the inlet and outlet ports in hub member 3 would be situated in the central plane of the motor cylinders instead of being axially displaced,

the cylinder block 2 must not be integral or rigidly connected with the pump casing 6; it suffices when the cylinder block is connected for rotation with the pump casing and naturally the two members must be mutually centered. Such a disposition is shown in Fig. 11 at 93. The structure and operation of the transmission shown in this figure otherwise are identical with those of the transmission shown in Fig. 1.

Fig. 12 shows a detail modification in which the outlet passage 94 to the pump cylinders is formed by a central bore of the input shaft portion 4 discharging by a port 95 in output shaft 5 into manifold 48.

I claim:

1. A hydraulic transmission comprising a stationary housing, axially aligned input and output shafts rotatably mounted in the housing, a pump unit including an eccentric rotor carried by said input shaft, a pump cylinder block journalled on said rotor for relative rotation therewith, said pump cylinder block being provided with radial cylinder bores, pump pistons reciprocating in said bores, a pump casing mounted for joint rotation with said pump cylinder block, said pistons having piston rods pivotally fastened to said casing, crank means interconnecting said pump cylinder block and said pump casing, a motor unit including a motor cylinder block mounted for rotation with said output shaft, said motor cylinder block being provided with radial cylinder bores, motor pistons reciprocating in said cylinder bores, bearing means surrounding said aligned input and output shafts and mounted in said stationary housing for sliding movement transversely to the axis of rotation of said shafts, a motor casing rotatably mounted on said bearing means, said motor piston having piston rods pivotally fastened to said motor casing, said pump unit and said motor cylinder block being arranged side by side in close proximity to each other within said motor casing, the pump casing and the motor cylinder block being connected to form a single structure rotating as a whole, means operative for transversely moving said bearing means carrying the motor casing to control the eccentricity of the motor casing relatively to the axis of rotation of said input and output shafts, linkage means operatively connecting the motor casing to said structure to provide for synchronous rotation of said structure and motor casing upon a change of eccentricity of said motor casing, said pump cylinder block and said motor cylinder block being provided with ports for admitting and discharging working fluid to and from said radial cylinder bores, and working fluid conduits for connecting the outlet from the pump cylinders to the inlet of the motor-cylinders and the inlet of the pump cylinders to the outlet of the motor cylinders.

2. A hydraulic transmission comprising a stationary housing, axially aligned input and output shafts rotatably mounted in the housing, a pump unit including an eccentric rotor carried by said input shaft, a pump cylinder block journalled on said rotor for relative rotation therewith, said pump cylinder block being provided with radial cylinder bores, pump pistons reciprocating in said bores, a pump casing mounted for joint rotation with said pump cylinder block, said pistons having piston rods pivotally fastened to said casing, crank means interconnecting said pump cylinder block and said pump casing, an axially extending hub member carried by said stationary housing, a motor unit including a motor cylinder block supported on said hub member for rotation with said output shaft, said motor cylinder block being provided with radial cylinder bores, motor pistons reciprocating in said cylinder bores, bearing means disposed at opposite sides of said housing for sliding movement transversely to the axis of rotation of said shafts, a motor casing rotatably mounted on said bearing means, said motor pistons having piston rods pivotally fastened to said motor casing, said pump unit and said motor cylinder block being arranged side by side in close proximity to each other within said motor casing, the pump casing and the motor cylinder block being connected to form a single structure rotating as a whole, means operative for transversely moving said bearing means carrying the motor casing to control the eccentricity of the motor casing relatively to the axis of rotation of said input and output shafts, linkage means operatively connecting the motor casing to said structure to provide for synchronous rotation of said structure and motor casing upon a change of eccentricity of said motor casing, said pump cylinder block and said motor cylinder block being provided with ports for admitting and discharging working fluid to and from said radial cylinder bores, and working fluid conduits traversing said input shaft and said hub member for connecting the outlet from the pump cylinders to the inlet of the motor cylinders and the inlet of the pump cylinders to the outlet of the motor cylinders.

3. A hydraulic transmission comprising a stationary housing, axially aligned input and output shafts rotatably mounted in the housing, a pump unit including an eccentric rotor carried by said input shaft, a pump cylinder block journalled on said rotor for relative rotation therewith, said pump cylinder block being provided with radial cylinder bores, pump pistons reciprocating in said bores, a pump casing mounted for joint rotation with said pump cylinder block, said pistons having piston rods pivotally fastened to said casing, crank means interconnecting said pump cylinder block and said pump casing, an axially extending hub member carried by said stationary housing, one of said shafts extending axially through said hub member, a motor unit including a motor cylinder block supported on said hub member for rotation with said output shaft, said motor cylinder block being provided with radial cylinder bores, motor pistons reciprocating in said cylinder bores, bearing means disposed at opposite sides of said housing for sliding movement transversely to the axis of rotation of said shafts, a motor casing rotatably mounted on said bearing means, said motor pistons having piston rods pivotally fastened to said motor casing, said pump unit and said motor cylinder block being arranged side by side in close proximity to each other within said motor casing, the pump casing and the motor cylinder block being connected to form a single structure rotating as a whole, means operative for transversely moving said bearing means carrying the motor casing to control the eccentricity of the motor casing relatively to the axis of rotation of said input and output shafts for variation of the motor piston stroke, said hub member carrying the motor cylinder block extending through one of said bearing means on the side of the motor cylinder block remote of the pump unit, the output shaft extending through the other of said bearing means, linkage means operatively connecting the motor casing to said structure to provide for synchronous rotation of said struc-

ture and motor casing upon a change of eccentricity of said motor casing, said pump cylinder block and said motor cylinder block being provided with ports for admitting and discharging working fluid to and from said radial cylinder bores, and working fluid conduits traversing said input shaft and said hub member for connecting the outlet from the pump cylinders to the inlet of the motor cylinders and the inlet of the pump cylinders to the outlet of the motor cylinders.

4. A hydraulic transmission as claimed in claim 3, in which the input shaft extends through said hub member supporting the motor cylinder block, said fluid conduits in the input shaft and in said hub member extending to a point situated axially outside of said transversely movable bearing means carrying the motor casing and communicating with each other at a point situated outside of said bearing with respect to the motor casing.

5. A hydraulic transmission comprising a stationary housing, axially aligned input and output shafts rotatably mounted in the housing, a pump unit including an eccentric rotor carried by said input shaft, a pump cylinder block journalled on said rotor for relative rotation therewith, said pump cylinder block being provided with radial cylinder bores, pump pistons reciprocating in said bores, a pump casing mounted for joint rotation with said pump cylinder block, said pistons having piston rods pivotally fastened to said casing, crank means interconnecting said pump cylinder block and said pump casing, an axially extending hub member carried by said stationary housing, the input shaft extending axially through said hub member, a motor unit including a motor cylinder block supported on said hub member for rotation with said output shaft, said motor cylinder block being provided with radial cylinder bores, motor pistons reciprocating in said cylinder bores, bearing means disposed at opposite sides of said housing for sliding movement transversely to the axis of rotation of said shafts, a motor casing rotatably mounted on said bearing means, said motor pistons having piston rods pivotally fastened to said motor casing, said hub member extending inwardly from one side of the stationary housing through one of said bearing means, said pump unit and said motor cylinder block being arranged side by side in close proximity to each other within said motor casing, the pump casing and the motor cylinder block being connected to form a single structure rotating as a whole together with the output shaft, means operative for transversely moving said bearing means carrying the motor casing to control the eccentricity of the motor casing relatively to the axis of rotation of said input and output shafts, linkage means operatively connecting the motor casing to said structure to provide for synchronous rotation of said structure and motor casing upon a change of eccentricity of said motor casing, said pump cylinder block and said motor cylinder block being provided with ports for admitting and discharging working fluid to and from said radial cylinder bores, and working fluid conduits traversing said input shaft and said hub member for connecting the outlet from the pump cylinders to the inlet of the motor cylinders and the inlet of the pump cylinders to the outlet of the motor cylinders.

THEODOR MÜLLER.

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1,819,716	Mackenzie	Aug. 18, 1931
2,099,630	Schneider	Nov. 16, 1937
2,141,168	Bischof	Dec. 27, 1938
2,186,409	Ferris	Jan. 9, 1940
2,186,556	Robbins	Jan. 9, 1940
2,227,631	Carter	Jan. 7, 1941
2,419,059	de Villiers	Apr. 15, 1947