March 10, 1959 R. J. COLLION ET AL 2,876,704

HYDRAULIC TRANSFORMER

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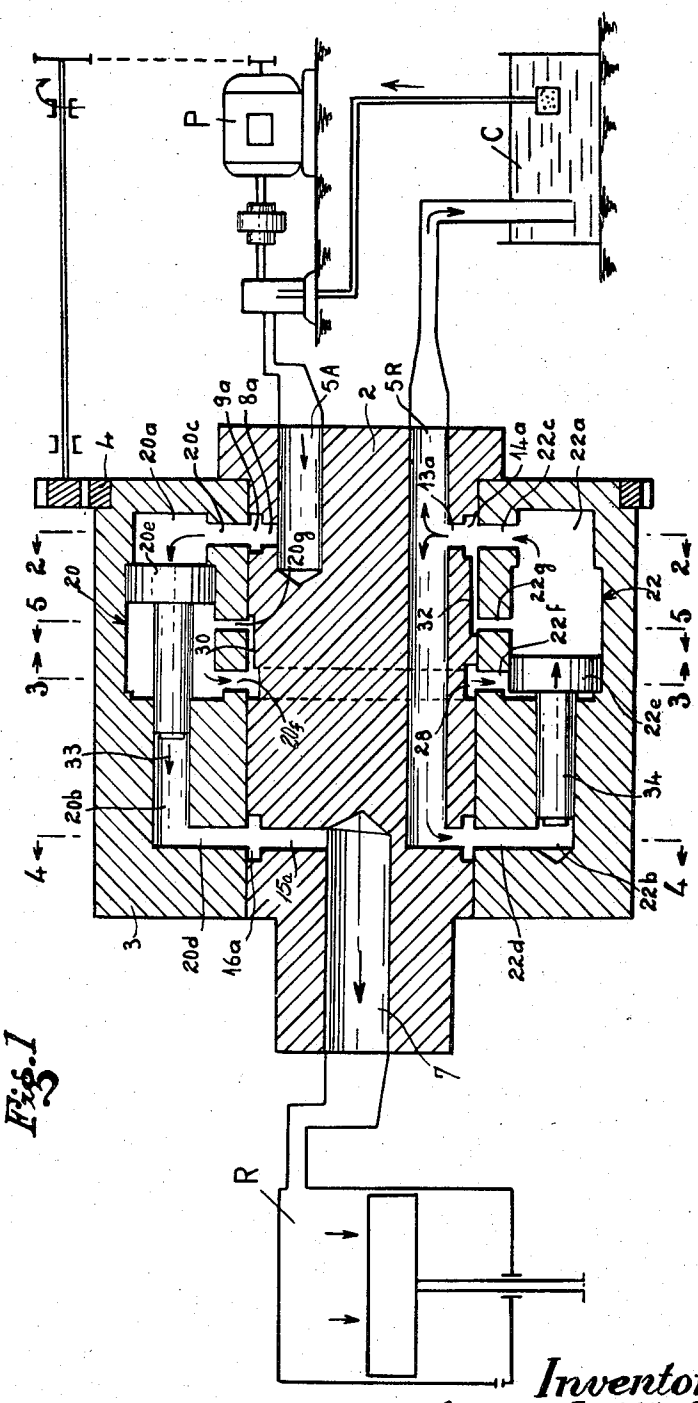


Fig. 1

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Fig. 2

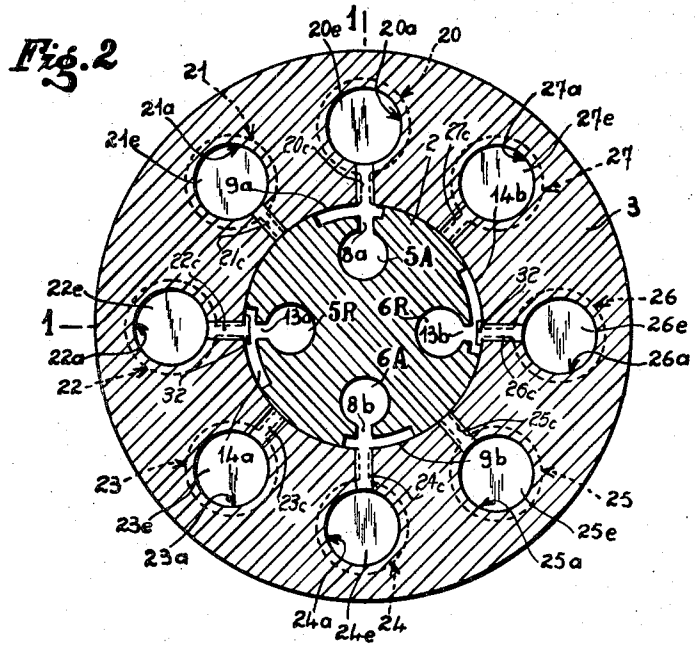
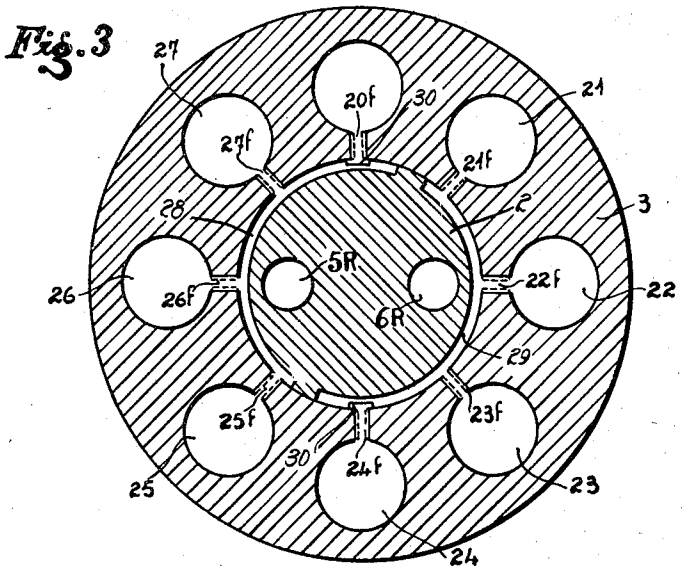


Fig. 3



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Fig. 4

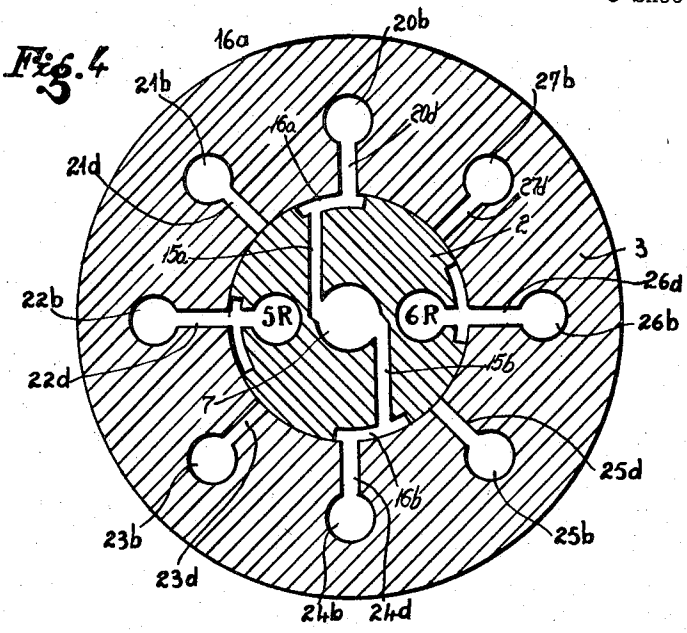
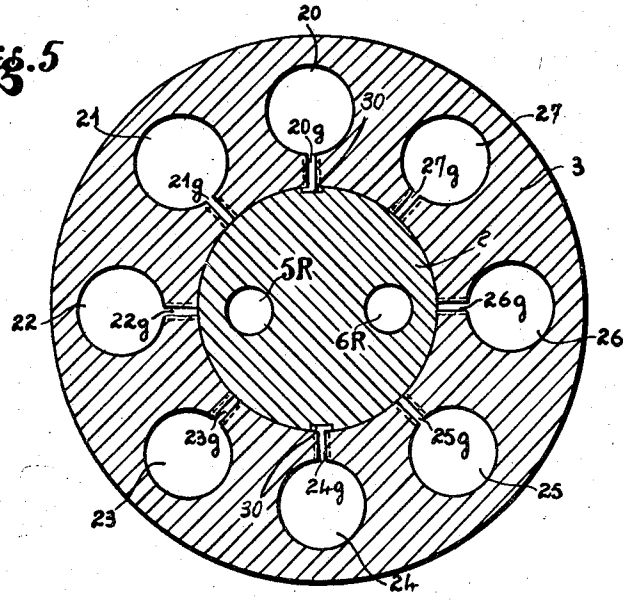


Fig. 5



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2,876,704

HYDRAULIC TRANSFORMER

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Claims priority, application France May 27, 1955

5 Claims. (Cl. 103—49)

Our invention has for its object an apparatus adapted to supply a liquid under a very high pressure and somewhat similar in certain respects to an electric transformer. It allows as a matter of fact obtaining starting from a liquid under a small pressure with a large output a liquid under a high pressure with a small output, the liquid under low pressure and large output conditions being obtained in any suitable manner for instance through a gear pump.

The hydraulic transformer according to our invention is more particularly of the type of certain apparatus already known in the art, which include a plurality of pressure-increasing cylinders controlled hydraulically and contained inside a rotor revolving round a stationary core through which said pressure-increasing cylinders are fed in succession with a view to obtaining a continuous high pressure output.

In spite of their simplicity, such transformers show however a serious drawback due to the fact that the volume of oil contained in each cylinder on the high pressure side of its piston is fed from the low pressure circuit, the capacity of the low pressure cylinder to the rear of the said piston being connected with the outer atmosphere. This leads to an alternation between low pressure and substantially zero pressure in the primary circuit, which under certain speed conditions is liable to produce vibrations.

On the other hand, and in a more essential manner, the mathematical yield of the transformer and more accurately the ratio of transformation of energy is:

$$\frac{K}{K+1}$$

K being the ratio of multiplication

$$\left(\frac{S}{s}\right)$$

which is not of advantage, in particular for low values of K, i. e. for small multiplication ratios. This is due to the fact that the oil in the low pressure circuit urges the piston rearwardly so as to fill the cylinder volume facing the small cross-sectional area of the piston, which volume has no action on the transformation work.

Our invention removes such drawbacks through the provision of a hydraulic transformer inside which the pistons are urged rearwardly without any further energy than that required for overcoming friction, the return movement of each piston being obtained through the progression of the other pistons as provided by a constant volume of oil enclosed behind the low pressure pistons in the corresponding interconnected cylinder sections.

In order that the volume of oil required for this rearward movement of the pistons may remain constant in spite of the leaks which may occur, the circuit interconnecting the low pressure cylinders is short-circuit in alternation through the oil container and through the primary circuit. This short-circuit ensures as a matter

of fact at the start the filling of said circuit under constant volume conditions.

To this end, there is provided at the periphery of the stationary core carrying the rotor an annular groove adapted to register with bores or perforations which connect it with the corresponding cylinders of the rotor inside the low pressure circuit to the rear of the low pressure cylinder sections while at least two longitudinal recesses shifted angularly with reference to each other connect each of the cylinders of the rotor through further bores alternatingly with the above mentioned groove so as to short-circuit or by-pass the volume of oil located to the rear of the pistons through the primary circuit and with a groove opening into the delivery channel so as to short-circuit said volume of oil through the container.

The number of cylinders in the rotor is irrelevant but it is preferably however an even number. Thus, in accordance with a preferred embodiment of our invention, the rotor includes eight cylinders arranged in drum formation round the stationary core and in each of said cylinders open two channels arranged radially, starting from the inner surface of the rotor, while the stationary core is provided with two grooves formed in a same plane, extending approximately over 170° of its periphery and adapted to register with one of two channels formed in the rotor for communication with the cylinders and two pairs of diametrically opposed recesses open respectively into the said first mentioned grooves and inside two delivery channels, the last mentioned recesses being adapted to register with the second of the two channels connected with each rotor cylinder.

We have illustrated by way of example in the accompanying drawings a preferred embodiment of this hydraulic transformer. In said drawings:

Fig. 1 is a longitudinal sectional view through the broken line I—I of Fig. 2.

Figs. 2, 3, 4 and 5 are cross-sections thereof through lines 2—2, 3—3, 4—4 and 5—5 of Fig. 1.

Said hydraulic transformer is chiefly constituted by a stationary core 2 and by an outer rotor 3 provided with a peripheral series of teeth 4 through which it may be driven into rotation round the hub 2.

Inside the core 2 are provided four longitudinal channels 5A, 5R and 6A, 6R opening into one of its terminal surfaces and a longitudinal channel 7 opening into its other terminal surface.

The two longitudinal oil-feeding channels 5A and 6A open through small radial channels 8*a* and 8*b* into corresponding arcuate grooves 9*a* and 9*b* formed in the core along a fraction of a cross-section thereof.

The two longitudinal oil-returning channels 5R and 6R communicate through two short radial channels 13*a* and 13*b* with two grooves 14*a* and 14*b* also formed along a peripheral arc of a cross-section of the rotor.

The longitudinal channel 7 in the core opens through two oblique channels 15*a* and 15*b* inside two grooves respectively 16*a*—16*b* similar to the arcuate grooves described precedingly.

As to the rotor 3, it includes eight cylinders arranged longitudinally in drum formation round its axis. These cylinders 20, 21, 22, 23, 24, 25, 26 and 27 communicate through their ends with two cylindrical chambers of a different diameter respectively 20*a*—20*b*, 21*a*—21*b*, 22*a*—22*b*, 23*a*—23*b*, 24*a*—24*b*, 25*a*—25*b*, 26*a*—26*b*, 27*a*—27*b*. Each of said chambers communicates with the inner surface of the rotor 3 through channels respectively 20*c*—20*d*, 21*c*—21*d*, 22*c*—22*d*, 23*c*—23*d*, 24*c*—24*d*, 25*c*—25*d*, 26*c*—26*d*, 27*c*—27*d*.

Inside each cylinder is fitted a differential stepped piston respectively 20*e*, 21*e*, 22*e*, 23*e*, 24*e*, 25*e*, 26*e*, 27*e* sliding through its larger diameter section inside the actual

cylinder **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27** and through its smaller diameter section in the cylindrical section of chamber **20***b*, **21***b*, **22***b*, **23***b*, **24***b*, **25***b*, **26***b*, **27***b*.

At the periphery of the stationary core 2, are provided:

Two grooves **28** and **29** located in a same transverse plane without communicating with each other (Fig. 3) and with said grooves **28** and **29** may register in succession the bores **20***f*, **21***f*, **22***f*, **23***f*, **24***f*, **25***f*, **26***f*, **27***f* provided inside the rotor 3 and connecting said grooves **28** and **29** with the corresponding cylinders **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27**.

Two recesses **30** extending along diametrically opposed generating lines of the outer cylindrical surface of the core and opening respectively into the groove **28** and into the groove **29**.

Two recesses **32** also extending along diametrically opposed generating lines of the outer surface of the core and shifted by 90° with reference to the recesses **30** (Fig. 1), said recesses opening respectively into the groove **14***a* of the core and into the groove **14***b* of said core (Fig. 2).

Eight bores **20***g*, **21***g*, **22***g*, **23***g*, **24***g*, **25***g*, **26***g*, **27***g* are formed radially inside the rotor and open each into the corresponding cylinders **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27** so as to connect it alternatingly with a recess **30** and with a recess **32** during rotation.

The operation of this hydraulic transformer is as follows:

A gear pump or the like feeding means delivers liquid under low pressure and high output conditions into the longitudinal channels 5A and 6A in the stationary core 2. The channels 5R and 6R are connected with the container C out of which said feeding means suck the liquid. The channel 7 is connected with the secondary circuit carrying the high pressure low output liquid.

When the pump P feeds thus into the primary circuit and the rotor is driven into rotation round the core 2, the liquid under low pressure and high output conditions feeds the cylindrical chamber **20***a* through the channel 5A, the radial channel 8*a*, the groove **9***a* and the channel **20***c*. At the same time, the liquid under low pressure and high output conditions feeds similarly liquid through the channel 6A into the diametrically opposed cylindrical chamber **24***a*. Consequently, the pistons **20***e* and **24***e* will move in the direction of the arrow 33 shown in Fig. 1 for the piston **20***e*. By reason of the presence of differential terminal surfaces on the pistons **20***e* and **24***e*, the latter compress the oil inside the chambers **20***b* and **24***b*. This oil which is brought to a high pressure is delivered into the secondary circuit through the channels **20***d* and **24***d*, the grooves **16***a* and **16***b*, the channels **15***a* and **15***b* and the central longitudinal channel **7** leading to the receiver R.

Simultaneously, the oil contained in the main cylinders **20** and **24** to the rear of the pistons **20***e* and **24***e* is driven by said pistons into the grooves **28** and **29** through the bores **20***f* and **24***f*. At the same moment, the cylinders **22** and **26** at 90° from the cylinders **20** and **24**, the pistons **22***e* and **26***e* of which cylinders **22** and **26** are at the end of their rearward stroke, communicate through their bores **22***f* and **26***f* with the channels **28** and **29**. Consequently the oil driven out of the cylinders **20** and **24**, as a consequence of the thrust exerted on the pistons **20***e* and **24***e* by the oil in the low pressure circuit, enters the cylinders **26** and **22** respectively and drives forwardly the pistons **22***e* and **26***e*. The shifting of said pistons **22***e* and **26***e* in the direction of the arrow **34** shown in Fig. 1 for the piston **22***e* produces a delivery of the oil in the low pressure circuit outside said cylinders. Said oil is driven through the channels **22***c* and **26***c* and the grooves **14***a* and **14***b* into the return channels 5R and 6R from which a fraction of the oil returns into the container while the remainder flows into the cylindrical chambers **22***b* and **26***b* of the high pressure circuit.

Simultaneously also, oil from the low pressure circuit feeds the grooves **28—29** through the perforations or bores **20***g*—**24***g* and the recesses **30** as soon as the pistons **20***e*—**24***e* have passed beyond said bores. Thus, the volume of the oil circuit ensuring the return of the pistons is restored, when required, to its normal value. Said oil flows furthermore freely and without any excess pressure since, as soon as the pistons **22***e* and **26***e* have moved beyond the bores **22***g*—**26***g*, any amount of excess oil will return to the container through said bores, through the recesses **32**, through the grooves **14***a*—**14***b* and through the return channels 5R and 6R.

This hydraulic constant volume arrangement which allows one piston to recede when another progresses improves considerably the efficiency of the apparatus. Furthermore, said arrangement considered alone without the pressure multiplying means may be provided for equipping injecting or the like presses operating in accordance with an automatic cycle.

Obviously, our invention is by no means limited to the embodiment of this hydraulic transformer disclosed hereinabove by way of exemplification and it covers all the modifications thereof falling within the scope of the accompanying claims.

What we claim is:

1. A hydraulic transformer comprising a cylindrical stator, a rotor revolubly and fluidtightly mounted on the stator and provided with a plurality of equal stepped cylinders distributed uniformly round the axis of the rotor, the axes of which cylinders are parallel with the axis of the rotor, said cylinders including each in sequence in a common predetermined direction, a slightly narrower outer section, a slightly broader inner section and a coaxial narrower extension, a stepped piston freely slidable in the inner section of each cylinder and in the extension thereof, distributing means feeding liquid under low pressure high output conditions through the stator into the outer sections of the successive rotor cylinders as the latter pass in front of predetermined equally distributed points of the stator, means interconnecting the inner sections of the successive cylinders registering with the arc extending between any two successive last mentioned points, said successive cylinders including one cylinder registering with the first of said points and excluding the cylinder registering with the second of said points, the inner sections of said successive cylinders forming with last mentioned means a capacity of unvarying volume, a secondary high pressure small output circuit subjected to the pressure of the piston ends progressing in the extensions of successive cylinders upon operative progression of the pistons under the action of the liquid fed into the corresponding outer sections against the liquid in the corresponding unvarying capacity and means wherethrough the liquid is exhausted through the stator out of the outer sections of those cylinders in which the pistons recede under the pressure of the liquid flowing in the corresponding capacity of unvarying volume, out of the inner sections of the cylinders connected with the same capacity and in which the pistons are subjected to the pressure of the liquid fed by the distributing means into the outer sections of said cylinders.

2. A hydraulic transformer comprising a cylindrical stator, a rotor revolubly and fluidtightly mounted on the stator and provided with a plurality of equal stepped cylinders distributed uniformly round the axis of the rotor, the axes of which cylinders are parallel with the axis of the rotor, said cylinders including each in sequence in a common predetermined direction, a slightly narrower outer section, a slightly broader inner section and a coaxial narrower extension, a stepped piston freely slidable in the inner section of each cylinder and in the extension thereof, distributing means feeding liquid under low pressure high output conditions through the stator into the outer sections of the successive rotor

cylinders as the latter pass in front of predetermined equally distributed points of the stator, means interconnecting the inner sections of the successive cylinders registering with the arc extending between any two successive last mentioned points, said successive cylinders including one cylinder registering with the first of said points and excluding the cylinder registering with the second of said points, the inner sections of said successive cylinders forming with last mentioned means a capacity of unvarying volume, a secondary high pressure small output circuit subjected to the pressure of the piston ends progressing in the extensions of successive cylinders upon operative progression of the pistons under the action of the liquid fed into the corresponding outer sections against the liquid in the corresponding unvarying capacity, means wherethrough the liquid is exhausted through the stator out of the outer sections of those cylinders in which the pistons recede under the pressure of the liquid flowing in the corresponding capacity of unvarying volume, out of the inner sections of the cylinders connected with the same capacity and in which the pistons are subjected to the pressure of the liquid fed by the distributing means into the outer sections of said cylinders, and means for connecting alternatingly during the rotation of the rotor the inner sections of each cylinder with the distributing means towards the end of the operative stroke of the corresponding piston urged inwardly by the liquid fed by said distributing means and with the exhaust means towards the end of the return stroke of the corresponding piston.

3. A hydraulic transformer comprising a stator provided with arcuate grooves in a transverse cross-section and with peripheral pairs of angularly shifted longitudinal peripheral recesses of which one opens into the corresponding peripheral groove, a rotor revolubly and fluidtightly mounted on the stator and provided with a plurality of stepped cylinders including a narrower outer and a broader inner section located at different angular locations, the axes of which cylinders are parallel with the axis of the rotor, and with a still narrower coaxial extension for each cylinder, said rotor being further provided with pairs of radial bores connecting the two sections of each cylinder with the inner surface of the rotor, the inner ends of the bores connected with the inner sections of the cylinders registering with the above mentioned cross-section of the stator to communicate during rotation of the rotor with the grooves therein to interconnect said rear sections and to form therewith corresponding unvarying capacities a stepped piston freely slidable in the inner section of each cylinder and in its extension, distributing means for feeding liquid under low pressure high output conditions through the stator into the bores leading to the outer sections of the rotor cylinders in succession, a secondary high pressure small output circuit fed by the cylinder extensions in succession upon operative progression of the different pistons under the action of the liquid fed into the corresponding outer sections against the liquid in the corresponding unvarying capacity, means connected with the longitudinal peripheral recesses which do not open into the peripheral grooves, wherethrough the liquid is exhausted through the stator out of the radial bores opening into those cylinder outer sections into which the pistons deliver fluid under the pressure of the liquid in the corresponding unvarying capacity flowing out of the other inner cylinder sections in which the pistons are subjected to the pressure of the liquid fed by the distributing means, means wherethrough the peripheral recesses opening into the peripheral grooves of the stator connect the latter and therewith the corresponding unvarying capacities with the distributing means through the outer sections of those cylinders in which the piston is near the end of its operative stroke towards the corresponding cylinder extension and means wherethrough the other peripheral recesses which do not open into the peripheral grooves connect the said unvarying capacities with the exhaust means through the inner sections of the cylinders in which the piston is near the end of its return stroke.

4. A hydraulic transformer comprising a cylindrical stator, a rotor revolubly and fluidtightly mounted on the stator and provided with a plurality of equal stepped cylinders distributed uniformly round the axis of the rotor, the axes of which cylinders are parallel with the axis of the rotor, said cylinders including each in sequence in a common predetermined direction, a slightly narrower outer section, a slightly broader inner section and a coaxial narrower extension, a stepped piston freely slidable in the inner section of each cylinder and in the extension thereof, distributing means feeding liquid under low pressure high output conditions through the stator into the outer sections of the successive rotor cylinders as the latter pass in front of predetermined equally distributed points of the stator, means interconnecting the inner sections of the successive cylinders registering with the arc extending between any two successive last mentioned points, the inner sections of said successive cylinders forming with last mentioned means a capacity of unvarying volume, means wherethrough the liquid is exhausted through the stator out of the outer sections of those cylinders in which the pistons recede under the pressure of the liquid flowing in the corresponding capacity of unvarying volume, out of the inner sections of the cylinders connected with the same capacity and in which the pistons are subjected to the pressure of the liquid fed by the distributing means into the outer sections of said cylinders, a secondary high pressure small output circuit and means extending through the rotor and adapted to connect in succession the extensions of the cylinders the outer sections of which are connected with the distributing means, with the secondary circuit and to connect in succession the extensions of the cylinders, the outer sections of which communicate with the exhaust means, with said exhaust means.

5. A hydraulic transformer comprising a stator provided with two arcuate grooves extending each at about 170° in a transverse cross-section and with two diametrically opposed peripheral pairs of angularly shifted longitudinal peripheral recesses of which one opens into the corresponding peripheral groove, a rotor revolubly and fluidtightly mounted on the stator and provided with eight stepped cylinders the axes of which are distributed on a circle coaxial with the stator at uniformly spaced angular locations, the axes of which cylinders are parallel with the axis of the rotor, said cylinders including each an outer section, a slightly broader inner section and a coaxial extension, said rotor being further provided with pairs of radial bores connecting respectively the two sections of each cylinder with the inner surface of the rotor, the inner ends of the bores connected with the inner sections of the cylinders registering with the above-mentioned cross-section of the stator to communicate during rotation of the rotor with the grooves therein to interconnect said rear sections and to form therewith two corresponding unvarying capacities, a stepped piston freely slidable through its larger cross-sectional section in the inner section of each cylinder and through its smaller cross-sectional area in the corresponding extension, two diametrically opposed distributing pipes adapted to feed liquid under low pressure high output conditions through the stator into the bores leading to the outer sections of the successive rotor cylinders, a secondary high pressure small output circuit fed by the successive cylinder extensions upon operative progression of the different pistons under the action of the liquid fed into the corresponding outer sections against the liquid in the corresponding unvarying capacity, two diametrically opposed channels connected through the stator with the longitudinal pe-

ripheral recesses which do not open into the peripheral grooves, where through the liquid is exhausted through the stator and through the radial bores opening into the outer cylinder sections in which the pistons recede under the pressure of the liquid in the corresponding unvarying capacity flowing out of the inner cylinder sections in which the pistons are subjected to the pressure of the liquid fed by the distributing pipes, means wherethrough the peripheral recesses opening into the peripheral grooves of the stator connect the latter and therewith the corresponding unvarying capacities with the corresponding distributing pipes through the outer sections of those cylinders in which the piston is near the end of its operative stroke and means wherethrough the other peripheral recesses connect the said unvarying capacities with the exhaust channels through the outer sections of the cylinders in which the piston is near the end of its return stroke.

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