

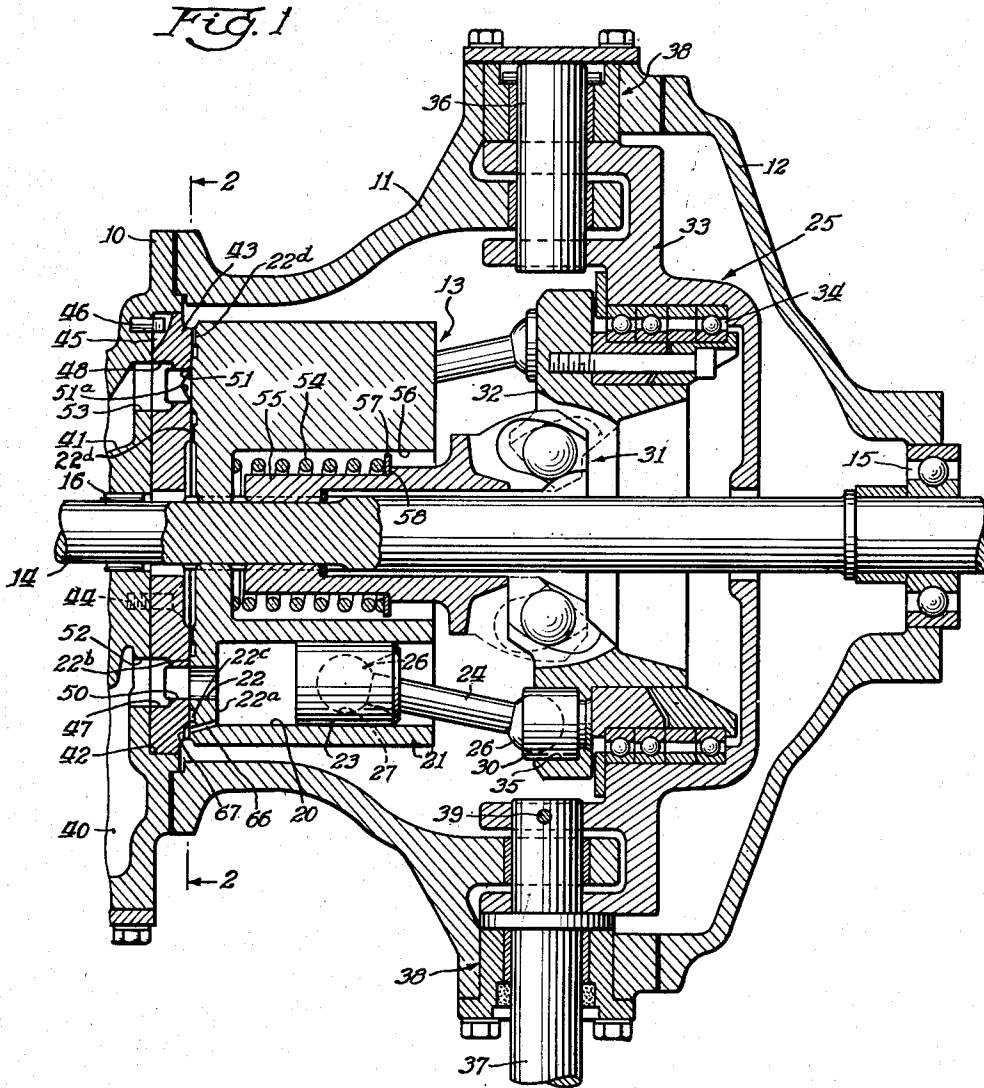
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J. A. LAUCK ET AL
MOTOR PORT CONSTRUCTION

2,633,104

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2 SHEETS—SHEET 1



Inventors:
John A. Lauck and
Fred C. Haberland
By *Edward Ditzler*
Att'y

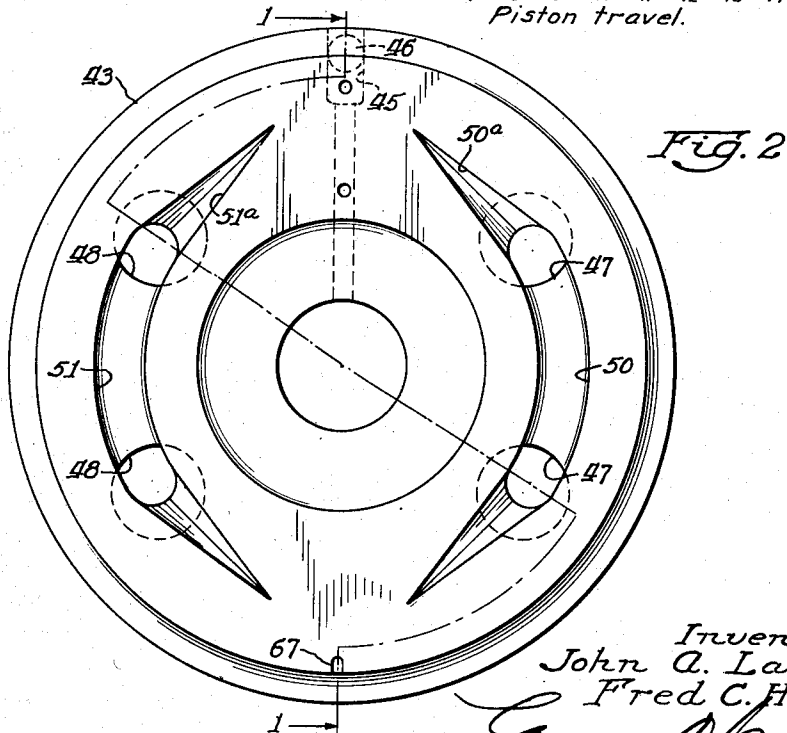
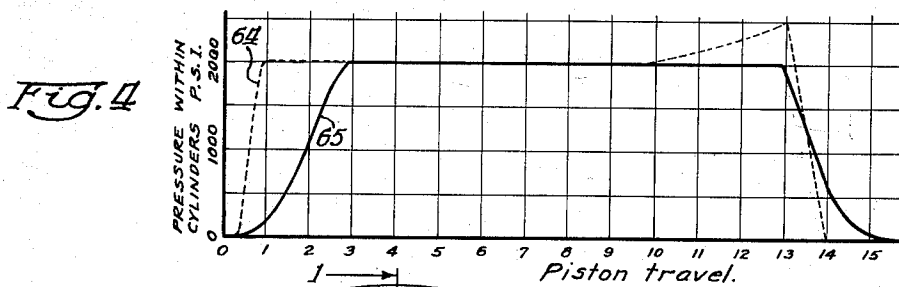
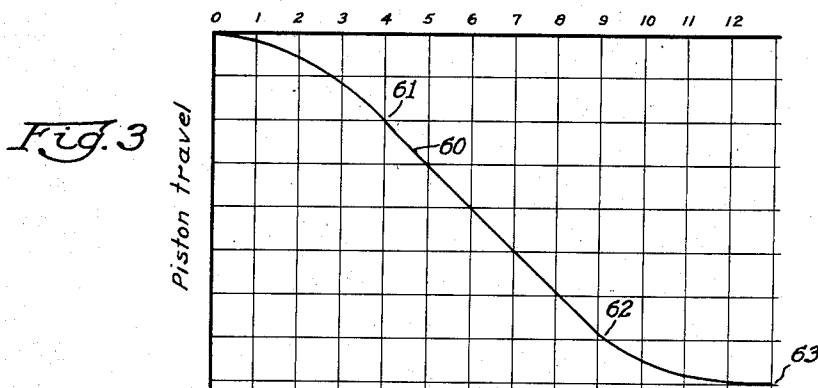
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2 SHEETS—SHEET 2



Inventors:
John A. Lauck and
Fred C. Haberland
By *Edward C. Ditzler*
Att.

UNITED STATES PATENT OFFICE

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MOTOR PORT CONSTRUCTION

John A. Lauck, Shaker Heights, and Fred C. Haberland, Cleveland, Ohio, assignors to Borg-Warner Corporation, Chicago, Ill., a corporation of Illinois

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5 Claims. (Cl. 121-62)

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This invention relates to a transmission, and more particularly to a hydraulic transmission of the type employing a fluid pressure generator and a fluid pressure motor.

Hydraulic transmissions, and particularly hydrostatic transmissions are well known to the transmission art, such transmissions being designed to enable a continuous variation of torque ratio over a wide range. Such a transmission may comprise a variable displacement hydraulic motor of the type having a cylinder block with a plurality of axially reciprocable pistons disposed therein and arranged to cooperate with a swash or wobble plate, the inclination of which may be varied to control the displacement of the motor, and wherein the cylinder ports formed at one end of the cylinder block bear against a manifold plate associated with a pressure control assembly, the ports alternately registering with pressure and suction ports in the manifold plate. It has been found that such transmissions in some cases are excessively noisy in operation. Furthermore, it has been found that when one cylinder is at the dead center position, that is located between manifold plate openings, it is sometimes very difficult to shift the swash plate of the hydraulic motor.

An object of the present invention is to provide a new and improved hydraulic transmission incorporating a porting arrangement of novel design.

A further object of the present invention is to provide a porting arrangement for a hydraulic transmission so designed as to insure quiet and efficient operation.

Another object of the present invention is to provide a porting arrangement for a hydraulic transmission which will facilitate shifting the swash plate under all operating conditions.

In accordance with one embodiment of this invention, a variable displacement hydraulic motor of the type including a plurality of radially disposed pistons and cylinders and an associated swash plate serving as the reaction member whereby torque is transferred to a driven shaft has associated therewith an accumulator or manifold arrangement for controlling the application of fluid pressure to the motor. The pressure and suction ports of the manifold plate adapted to register with the ports of the hydraulic motor cylinders are elongated and tapered at either end in such manner that actuating fluid pressure is applied to the piston cylinders sequentially at a rate in direct proportion to the piston velocity at any instant from top dead center position to bottom dead center of travel.

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Further, registering holes are provided in the manifold plate and in the cylinder block whereby when one cylinder is at the dead center position or where a port of the hydraulic motor is positioned between two of the manifold plate ports, fluid may be admitted to the cylinder chamber to permit shifting the inclination of the swash or wobble plate of the hydraulic motor.

Other objects and advantages of the present invention will be apparent from the following detailed description taken in conjunction with the drawings wherein:

Fig. 1 is a fragmentary, axial, sectional view taken substantially along the line 1-1 of Fig. 2 of a transmission constructed in accordance with one embodiment of this invention and showing primarily the variable displacement hydraulic motor and associated pressure control or manifold arrangement;

Fig. 2 is a view of the manifold porting plate taken along the line 2-2 of Fig. 1;

Fig. 3 is a graph showing the travel of a piston during 180° of a cycle; and

Fig. 4 is a graph showing the pressure within a cylinder plotted against piston travel with a conventional porting arrangement and the pressure within a cylinder plotted against travel with the novel porting arrangement of the present invention.

Referring now to Fig. 1, it will be seen that a part of a transmission housing comprising sections 10, 11 and 12 is there illustrated; these sections constituting the right end of the transmission housing and enclosing therewithin a hydraulic motor of the variable displacement type designated generally at 13. An output shaft 14 extends axially through the housing sections 10, 11 and 12 and is rotatably supported therein at its right end by annular bearing assembly 15 mounted in the right end wall of housing section 12 and at its left end by roller bearings 16 positioned about the periphery of the left portion of shaft 14.

Hydraulic motor 13 comprises a plurality of equally radially spaced cylinders 20 formed in a cylinder block 21, the cylinders 20 being disposed in annular array and extending axially therethrough, and the left ends of the cylinders 20 terminating in ports 22 of substantially reduced cross-section. The inner end wall portions 22a of ports 22 form pressure responsive motive areas for urging cylinder block 21 into sealing engagement with a manifold porting plate 43, described in detail hereinafter. These motive areas are carefully proportioned with respect to the outer areas 22b at the left end of the block

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21 so that the total area of areas 22a exceeds that of 22b by a slight margin in accordance with established pressure loading practice. A pair of radially spaced, annular grooves 22c formed in the left end surface of block 21 and disposed coaxially of shaft 14 define the inner and outer periphery of areas 22b and communicate with the sump of the transmission through radially outwardly extending grooves 22d, as shown in Fig. 1.

Cylinder block 21 is supported on and splined to shaft 14, and a piston 23 is slidably journaled in each of the cylinders 20. Each piston 23 has associated therewith a piston rod 24 whereby connection is made between the piston and a swash or wobble plate assembly designated generally at 25. To provide a suitable connection, at each end of each connecting rod 24 a ball 26 is mounted, the ball at the left end being received in a suitable spherical recess 27 formed in the associated piston, while the ball at the right end of the connecting rod is received in a socket cup 30 mounted in the swash plate 25. These spherical terminations permit angular displacement of the connecting rods 24 with respect to the axis of reciprocation of the pistons 23 as the position or inclination of the swash plate 25 is changed.

More specifically, the swash plate assembly 25 comprises an inner, annular, dish-shaped socket housing 32 which is pivotably supported on a constant velocity universal joint 31 and an outer, generally annular, supporting carrier or bed 33, the angular position of which may be varied with respect to shaft 14 about an axis lying transverse to the axis of shaft 14. A constant velocity universal joint is essential in order that uniformity of transmission of motion be provided. In a constant velocity universal joint of the type illustrated, the point of contact, or of motion transfer, is always at equal radial distances from the axes of the two elements, that is the point of contact always lies in the plane bisecting the angle between the connected elements. Constant velocity universal joint 31 is of generally conventional design and is splined on shaft 14 adjacent the right end of a motor block 21. An annular bearing assembly 34 is interposed between the outer member 33 of the swash plate and the socket housing 32 so that the socket housing 32 may rotate with respect to the outer member 33 in a plane determined by the angular position of the outer member. The socket cups 30 are disposed in annular array about the left face of housing 32, being received in suitable apertures 35 formed in the housing and secured to the housing as by welding or swaging.

Outer member or carrier 33 is supported on a pair of oppositely disposed, radially extending stub shafts 36 and 37, as shown in Fig. 1, journaled in suitable, axially aligned trunnion bearings indicated generally at 38, which bearings are mounted between the housing sections 11 and 12. Stub shaft 37 is keyed to the angularly adjustable carrier 33 of the swash plate 25 by a pin 39 which extends transversely through the shaft and into the carrier. Thus, by rotating shaft 37, the angular adjustment or inclination of the swash plate assembly 25 may be controlled.

It will be evident that with this arrangement, torque is applied to the shaft 14 from the socket ring which is, in effect, splined to the shaft, through supporting universal joint 31. The swash plate assembly is thus pivotable about the axis of stub shafts 36 and 37, and the socket housing 32, while rotatable relatively to the sup-

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porting carrier 33 as the hydraulic motor block and shaft 14 are rotated, is not rotatable with respect to shaft 14. By rotating stub shaft 37 and thereby pivoting carrier 33, the relative inclination of swash plate assembly 25 may be changed, and the effective displacement of the hydraulic motor may thus be varied from a minimum when the plate is at right angles to shaft 14 to a maximum as the inclination toward the shaft 14 is reduced in either direction.

In order to control the application of pressure to the hydraulic motor, the pressure control assembly housing 10 mounted at the left end of motor housing section 11, has formed therein a pressure chamber 40 and a suction chamber 41. Both chambers are suitably connected through ducts, not shown, to a pressure generator, such as a gear pump, the chamber 40 being connected to the outlet side of the pump and the chamber 41 being connected to the inlet side thereof. A suitable arrangement is shown and described in the co-pending application of Minshall et al., Serial No. 104,924 filed July 15, 1949.

The right end wall of housing section 10 has a wide recess 42 of generally cylindrical configuration formed therein to receive the manifold porting plate 43, and plate 43 is rigidly secured to housing 10 by bolts 44. It will be noted that a slot 45 is formed in the upper edge of the porting plate, as viewed in Fig. 1, and a locating pin 46 mounted in the right end wall of the housing section 10 extends into the slot 45. This pin and the cooperating slot facilitate proper location of the manifold porting plate during assembly of the transmission. Manifold porting plate 43 has formed therein on the left side thereof, as viewed in Fig. 1, two sets of cylindrical porting recesses 47 and 48, respectively, which communicate at their right ends with two generally arcuate kidney ports 50 and 51, respectively, formed by recessing the right surface of plate 43. Kidney port 50 constitutes the pressure port of this transmission in normal operation and registers at the left side thereof, as viewed in Fig. 1, through porting recesses 47 with the right end of a passage 52, the left end of passage 52 connecting with pressure chamber 40. Similarly, the left side of kidney port 51 registers through porting recesses 48 with the right end of a passage 53 formed in housing section 10, and the left end of passage 53 connects with suction chamber 41.

Ports 22 formed at the left ends of cylinders 20 of the hydraulic motor are arranged so that as the motor block 21 rotates on the shaft 14, the ports 22 will sequentially register with the kidney ports 50 and 51 in the manifold porting plate, thus alternately applying pressure and then suction to the cylinders. When the motor is operating the pressure in the cylinders, by virtue of the selection of pressure areas 22a and 22b, is sufficient to provide a tight seal between the left end surfaces of the motor block and the right end surfaces of the manifold plate 43, both of which surfaces are ground flat and smooth. In order to maintain these surfaces in suitable contact when no load is transmitted, however, a helically coiled spring 54 is disposed on a sleeve portion 55 of the universal joint 31, the sleeve 55 being mounted on and keyed to shaft 14 and extending into a deep cylindrical recess 56 formed at the center of the motor cylinder block. The left end of spring 54 bears against the inner end wall of recess 56, while the right portion of spring 52 bears against a re-

taining ring 57, which is held in position on sleeve 55 by a shoulder 58 formed about the periphery of the sleeve 55 adjacent its right end.

Heretofore, it has been the general practice to form the arcuate kidney ports 50 and 51 in a coring operation whereby the ends of the ports were slightly tapered but on the whole of generally semicylindrical configuration. In accordance with the present invention, however, it has been discovered that the configuration of the kidney ports, and particularly the terminations thereof, must be critically designed in order to obtain smooth and efficient operation of the transmission and to avoid the objectionably noisy operation, heretofore often considered an inherent characteristic of this type of transmission.

In Fig. 3, a curve 60 is presented illustrating the travel of a hydraulic motor piston from top dead center to bottom dead center position, Fig. 3 thus illustrating half of a piston cycle, both halves of the cycle being identical. From this graph it will be noted that the initial movement of the piston, starting from the rest position, which coincides with vertical line 0, is one of increasing acceleration. By the time the piston has reached a position designated at 61 and approximately coinciding with vertical line 4, a substantially constant velocity is reached. The velocity remains constant then during the major portion of piston travel and until a position designated at 62 is reached, coinciding approximately with vertical line 9, after which the piston begins to slow down preparatory to stopping and reversing direction of movement. At position 63, representing bottom dead center, the piston is again at rest. This curve is typical of normal operation and may be regarded as characteristic of piston travel in this type of motor.

Referring now to Fig. 4, wherein a curve 64 is presented representing the pressure within a cylinder plotted against piston travel during the power stroke using a conventional cord porting arrangement, as described, it will be evident that as the cylinder port 22 begins to register with the end of a conventional kidney port there is an initial momentary, gradual application of pressure, but when the port 22 has moved only a very short distance, full registry is obtained and maximum pressure is abruptly applied. This maximum pressure is thus applied prior to the time that piston travel has reached or can reach maximum velocity, that is, the zone of constant velocity, and consequently the piston is undesirably loaded. After the piston has delivered its useful work during the power stroke portion of its cycle of operation and has begun to slow down, that is to say is operating on the portion of curve 60 lying between points 62 and 63 in Fig. 3, maximum pressure is still applied since it is desirable that the piston deliver full power to the end of its power stroke. Actually, there may be an actual sharp chamber pressure increase immediately preceding the pressure exhaust phase due to the failure of prior porting arrangements to provide a graduated reduction in inlet flow proportioned to the deceleration of the piston as it reaches the end of its power stroke. Thereafter, upon registration of the motor port with the exhaust passage in the porting plate there is an equally abrupt release of pressure from the piston chamber. From the foregoing it will be evident that considerable pressure is wasted since during a substantial portion of piston travel in each cycle, the piston actually reacts against application of pressure rather than responds thereto. In

addition to this loss of power with resulting reduction in the possible efficiency of the transmission, the abrupt admission and release of pressure causes the transmission to be undesirably noisy.

In accordance with the present invention, the terminations of each of the kidney ports 50 and 51 are tapered in such a manner that the rate of flow of the fluid entering the cylinders is made to be in direct proportion to the piston velocity at any instant from top dead center position to bottom dead center position. Stated otherwise, the kidney ports are so constructed and their ends are tapered so that the volume of fluid flow into the piston chamber at any instant is proportioned or selected to provide a piston energizing pressure commensurate with the capacity of the piston to react or move at that instant. Thus, instead of abruptly applying maximum fluid pressure to the piston during the initial phase of movement when the piston is moving relatively slowly and can only move relatively slowly, the pressure in accordance with this invention is also applied relatively slowly and at a rate selected to take maximum advantage of the travel characteristic of this type of piston without wasting fluid pressure. This not only results in materially increased operating efficiency but in a substantial reduction in the noise level.

Thus, referring to Fig. 2, what may be termed fish tails 50a and 51a are associated with each of the kidney ports 50 and 51 respectively, and the kidney ports themselves have been substantially shortened over the length conventionally employed, such as that shown, for example, in the previously referred to co-pending application of Minshall et al. The terminations 50a and 51a are thus so arranged that a graduated application and later withdrawal of pressure is provided paralleling insofar as possible the power stroke and exhaust stroke phases of piston travel, as shown in Fig. 3.

To some extent, the degree of taper of the fish tails 50a and 51a may be calculated in advance, since the degree of taper is directly related to the portion of the curve 60 lying between top dead center position and position 61 and also the portion of the curve lying between point 62 and bottom dead center position designated 63 in Fig. 3. For any particular transmission, however, it has been found that the final design must be worked out experimentally. Curve 65 of Fig. 4 represents a desirable pressure value characteristic applied to the piston, that is, the displacement chamber within the motor cylinder plotted against piston travel from the start position, or bottom dead center, of the power stroke through the end of the power stroke and to approximately the beginning of the constant velocity portion of the exhaust stroke. From this curve it will be evident that pressure is applied at a gradually increasing rate starting from bottom dead center position and over substantially the entire accelerating portion of travel of the piston. Thus, for example, considering the direction as being clockwise as to Fig. 2, a motor port registers at its right edge with the upper tapered termination 50-a of pressure port 50 and as the cylinder block rotates gradually fluid pressure is admitted at an increasing rate of flow, as the motor port progressively registers more fully with the wider sections of the tapered termination. The motor port thereafter registers with the widest but substantially constant width portion of the kidney port during the period of maximum but substantially constant velocity of

the piston, thus tending to provide a constant value maximum chamber pressure during this period of maximum piston velocity. Thereafter, as the motor port begins to register with the start of the tapered termination at the lower end of kidney port 50, the rate of flow of fluid into the piston chamber is gradually reduced paralleling the reduction in piston velocity but maintaining a constant chamber pressure value. If the rate of flow of fluid were not reduced concurrently with the reduction in velocity of the piston, and at a rate paralleling the reduction in piston velocity, there would be an undesirable rise in chamber pressure during the last part of the pressure stroke.

After the end of the piston power stroke, the associated motor port for an instant is in registry neither with the inlet kidney port nor the outlet kidney port and maximum pressure is maintained in the piston chamber. However, continued rotation of the motor block in a clockwise direction then brings the leading edge of the motor port in registry with the lower, tapered termination 51-a of the exhaust port 51. The operation here is the reverse of that during the power stroke, pressure in the piston chamber being released at a gradually increasing rate during the accelerating phase of piston travel on the exhaust stroke up to a maximum rate coinciding with the maximum velocity phase of the exhaust stroke. The rate of exhaust is thereafter reduced to parallel the piston velocity characteristic during the decelerating phase of the piston exhaust stroke as the motor port registers with the upper tapered termination 51-a of the exhaust port. It will be apparent that the present arrangement lends itself equally well to rotation of the motor block in either direction.

When the transmission is in a neutral position, that is to say, the vehicle with which it may be associated is not moving, if a cylinder port 22 is located at the dead center position, that is located exactly between manifold plate porting openings, considerable difficulty may be encountered in attempting to shift the inclination of the swash plate assembly. This is due to the seal provided between the manifold porting plate and left end of the cylinder block whereby fluid is substantially prevented from either entering or leaving a cylinder when a cylinder port does not register at least in part with either an inlet or outlet manifold port. In accordance with this invention, in order to permit shifting of the swash plate so that the torque multiplication ratio of the transmission may be changed, means are provided for admitting fluid to or exhausting fluid from a cylinder even though the cylinder port is not in registry with a manifold port.

Referring to Fig. 1, it will be noted that a small aperture 66 is formed through the left end wall of cylinder block 21 radially outside of port 22, the aperture 66 extending at a slight downward angle, as viewed in this figure, from area 22a to below groove 22c. A short, radial slot 67 is formed in the adjacent surface of manifold plate 43 and is adapted to register at its radially inner end with the left end of aperture 66 when the associated port 22 is located between the two manifold plate ports 50 and 51. The other end of slot 67 communicates with the sump portion of the transmission. Thus, when an aperture 66 and slot 67 are in registry, oil may be readily exhausted from or taken into the associated cylinder, thereby facilitating shifting of the swash plate.

Where herein the various parts of this invention have been referred to as being located in a right or a left or an upper or lower position, it will be understood that this is done solely for the purpose of facilitating description and that such references relate only to the relative positions of the parts as shown in the accompanying drawings.

While but one embodiment of this invention has been shown and described, it will be understood that many changes and modifications may be made therein without departing from the spirit or scope of the invention.

What is claimed is:

1. In a hydraulic displacement device adapted to operate as either a hydraulic pump or motor, a piston associated with said device, and a manifold porting plate for controlling application of pressure to and release of pressure from said piston, said manifold porting plate having an exhaust port and a pressure port formed therein and said ports having uniformly tapered terminations, the cross sectional area of said tapered terminations at the point of junction with said port being equal to the cross sectional area of the port end portion, the remaining cross sectional area of said tapered terminations varying according to the characteristic rate of change of volumetric size of said power piston chamber accomplished by movement of said piston whereby the pressure of the fluid on said piston at any instant is in substantially direct proportion to the piston velocity at that instant.

2. In a hydraulic transmission including a hydraulic motor of the type having reciprocable pistons journaled in cylinders formed in a cylinder block, a shaft supporting said motor cylinder block and rotatable therewith, each of said cylinders having a port formed therein, a manifold plate for controlling application of pressure to said cylinders and having ports formed therein, said cylinder ports being adapted to register with said manifold plate ports, means for holding said manifold plate stationary with respect to said rotatable cylinder block, and each of said manifold plate ports having uniformly tapered terminations at either end thereof, the cross sectional area of each of said tapered terminations at the point of junction with said port being equal to the cross sectional area of the port end portion, the cross sectional area of the remaining portion of each of said tapered terminations varying according to the characteristic rate of change of volumetric size of said power piston chamber accomplished by movement of said piston so that the rate of flow of the fluid entering and leaving the cylinders through the ports at any instant is in substantially direct proportion to the piston velocity at that instant.

3. A hydraulic displacement device comprising means defining a piston chamber, a reciprocable piston in said chamber, said chamber having a port formed therein for admitting fluid to and releasing fluid from said chamber, a manifold plate associated with said piston chamber defining means, and having a pressure port and an exhaust port formed therein, said manifold plate ports and said chamber port being adapted to move into registry, and each of said manifold plate ports having uniformly tapered terminations at either end thereof, the cross sectional area of each of said tapered terminations at the point of junction with said port being equal to the cross sectional area of the port end portion, the remaining cross sectional area of each of

said tapered terminations varying according to the characteristic rate of change of volumetric size of said power piston chamber accomplished by movement of said piston whereby the rate of flow of the fluid passing through said chamber port at any instant is proportioned to the velocity of the piston at that instant.

4. A hydraulic motor including a cylinder block having a piston chamber formed therein, a piston reciprocable in said chamber, means defining a port associated with said chamber for controlling the admission of fluid pressure to and the release of fluid pressure from said chamber, said port having an elongated configuration with tapered terminations at either end and an intermediate portion joining said termination of uniform width and being arranged so that the effective size of said port at any instant is varied in accordance with the velocity at that instant of said piston, said effective size of said tapered terminations being accomplished by providing said tapered terminations with a cross sectional area equal to the cross sectional area of the port end portion and varying the cross sectional area of the remainder of said tapered terminations according to the characteristic rate of change of volumetric size of said power piston chamber accomplished by movement of said piston, one of said tapered terminations being arranged to provide a uniformly increasing application of hydraulic pressure to said piston chamber during the accelerating phase of the power stroke of said piston, the intermediate portion of said port providing a substantially constant pressure in said piston chamber during the substantially constant velocity phase of the power stroke, and the other of said terminations providing a substantially constant chamber pressure during the decelerating phase of the power stroke.

5. A hydraulic motor including a cylinder block having a plurality of piston chambers formed therein and disposed in annular array, a shaft supporting said cylinder block, a piston reciprocable in each of said chambers, each of said chambers having a port formed therein, a manifold plate having an exhaust port formed therein and a pressure port formed therein, said piston chamber ports being adapted to register successively with said pressure and said exhaust ports, each of said manifold plate ports having uniformly tapered terminations at either end thereof joined by an intermediate portion of

uniform width, each of said tapered terminations having a cross sectional area equal to the cross sectional area of the port end portion, the cross sectional area of the remainder of each of said tapered terminations varying according to the characteristic rate of change of volumetric size of said power piston chamber accomplished by movement of said piston, whereby each of said piston chamber ports in progressively registering with said pressure port first permits application of a uniformly increasing hydraulic pressure to the associated piston during the accelerating phase of the power stroke of the piston, then registering with the uniform diameter portion of the pressure port in the manifold plate permits application of a uniform rate of pressure flow to said piston, and finally registering with the tapered termination of the pressure port maintains a substantially uniform pressure in said piston chamber during the decelerating phase of the power stroke, and whereby said piston chamber port thereafter is progressively placed in communication with one tapered termination of the exhaust port so that during the accelerating phase of the exhaust stroke a uniformly increasing release of pressure from the piston chamber is permitted, then is progressively placed in communication with the uniform diameter portion of the exhaust port so that during the constant velocity phase of the exhaust stroke a constant rate of pressure release flow is permitted and finally is progressively placed in communication with the other tapered termination of the exhaust port so that during the decelerating phase of the exhaust stroke a uniformly decreasing release of pressure is permitted.

JOHN A. LAUCK.
FRED C. HABERLAND.

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