

[54] **STEP VARIABLE DISPLACEMENT  
HYDRAULIC MOTOR**[75] Inventors: **Richard Merle Kleckner**, Arlington Heights, Ill.; **James Henry Kress**, Cedar Falls, Iowa[73] Assignee: **Deere & Company**, Moline, Ill.[22] Filed: **Dec. 17, 1971**[21] Appl. No.: **209,154**[52] **U.S. Cl.**..... **91/492, 91/472**[51] **Int. Cl.**..... **F01b 1/06**[58] **Field of Search**..... 91/491, 492, 498, 91/180[56] **References Cited**  
**UNITED STATES PATENTS**

|           |         |                 |         |
|-----------|---------|-----------------|---------|
| 3,511,131 | 5/1970  | Kress .....     | 417/485 |
| 3,403,599 | 10/1968 | Guinot .....    | 91/491  |
| 3,369,457 | 2/1968  | Guinot .....    | 91/491  |
| 2,160,612 | 5/1939  | Alpern .....    | 60/53 B |
| 3,593,621 | 7/1971  | Praddaude ..... | 91/498  |

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[57] **ABSTRACT**

A hydraulic motor has a housing with an annular cam surface on the inner circumferential surface of the housing, the cam surface being generally sinusoidal and having a plurality of cam lobes at equiangular intervals. A rotatable cylinder block is mounted in the housing and has a plurality of radially extending cylinders having pistons with cam followers on their outer ends which engage the cam surface to cause the cylinder block to rotate in response to reciprocation of the pistons. Valve means are provided for sequentially connecting the cylinders to a pressure source or a return line to cause the reciprocation of the pistons, and additional valve means are provided to selectively cause each piston to complete one stroke for each cam lobe to provide a first motor displacement or to permit each piston to idle as it passes certain of the cam lobes to provide different motor displacements.

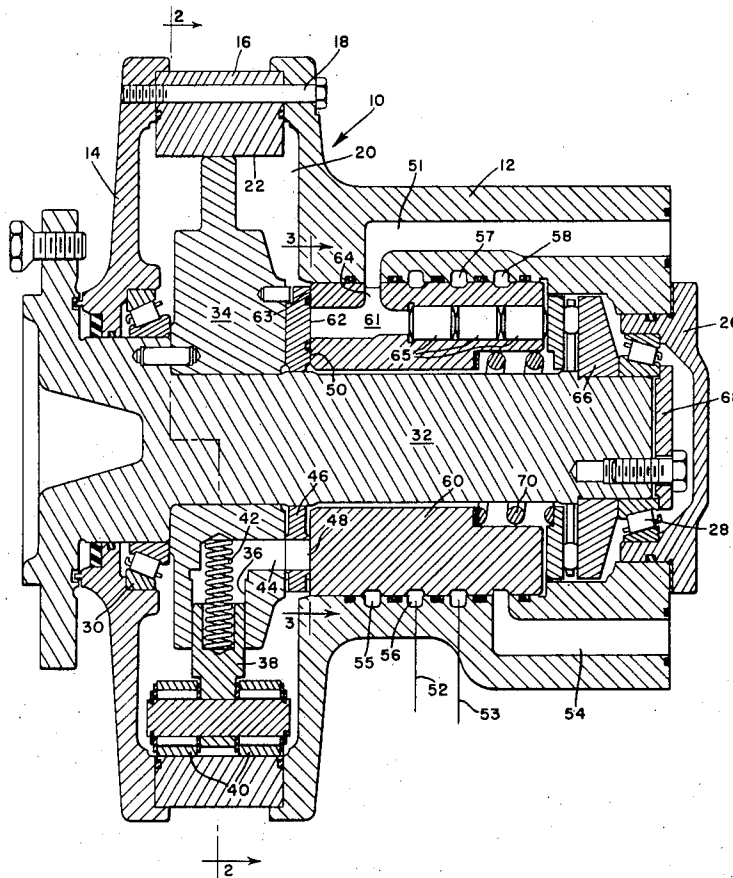
**1 Claim, 8 Drawing Figures**



FIG. 2

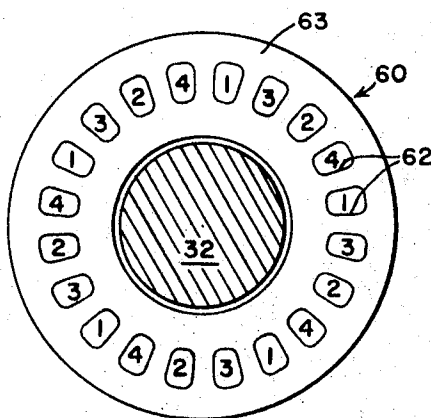
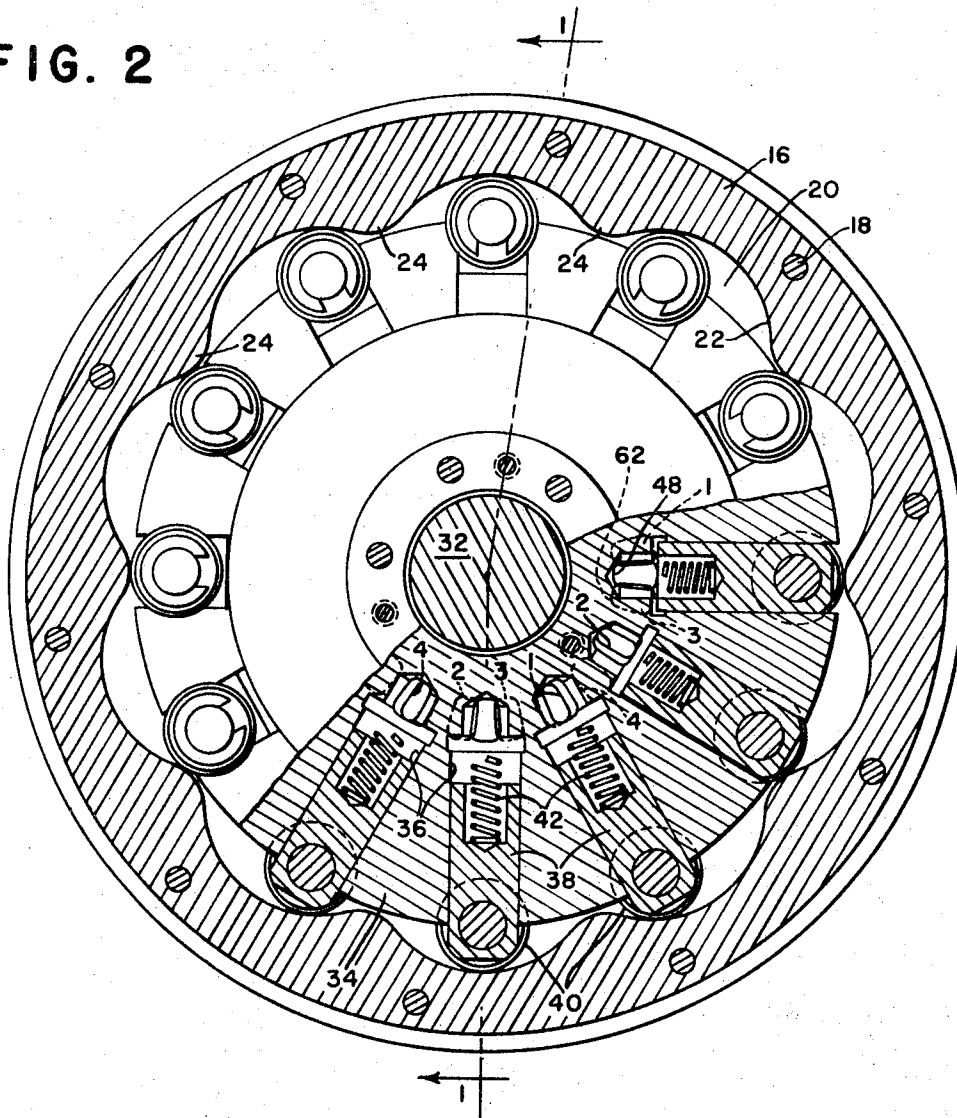
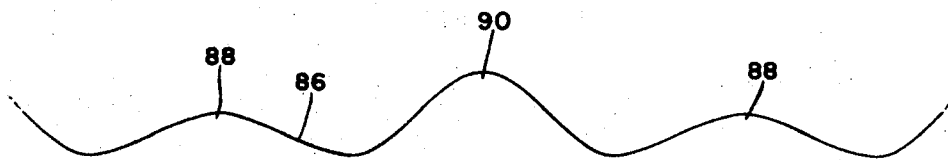
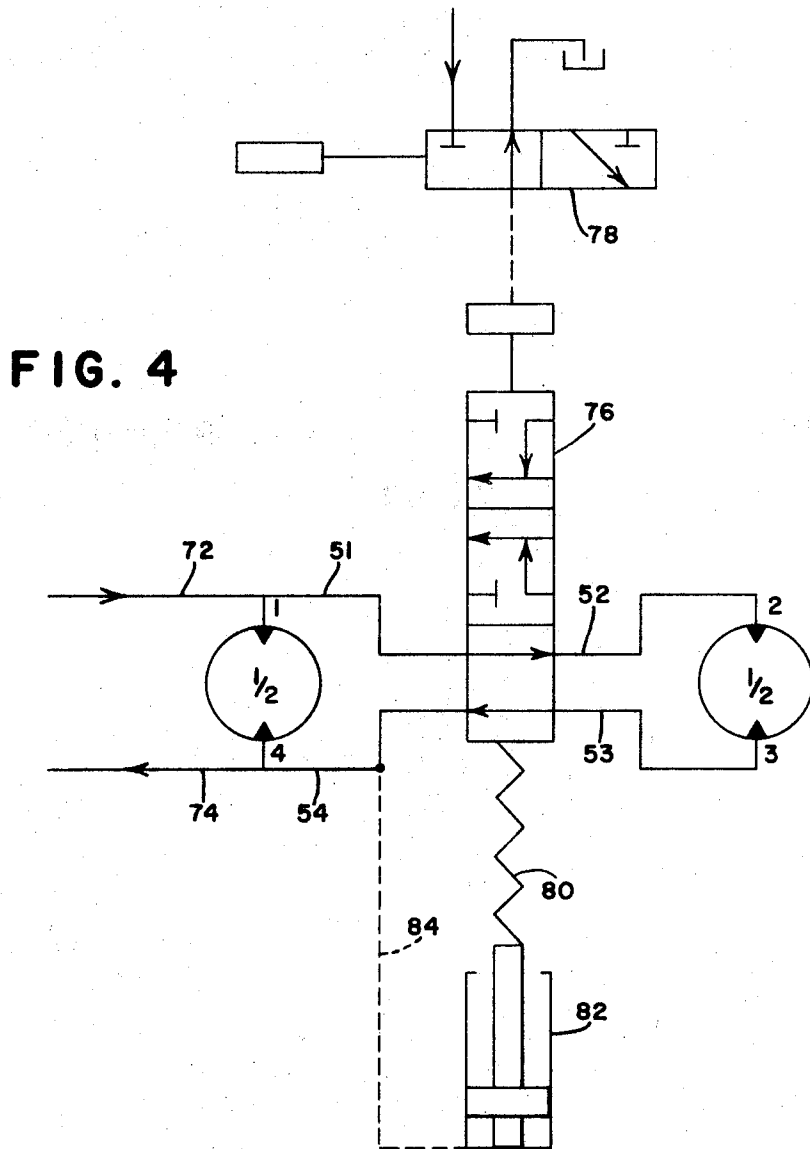


FIG. 3



**FIG. 5**

FIG. 6

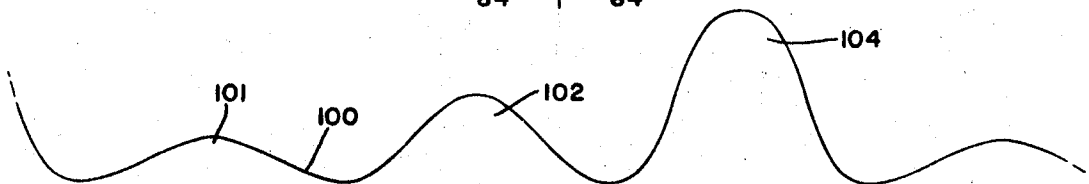
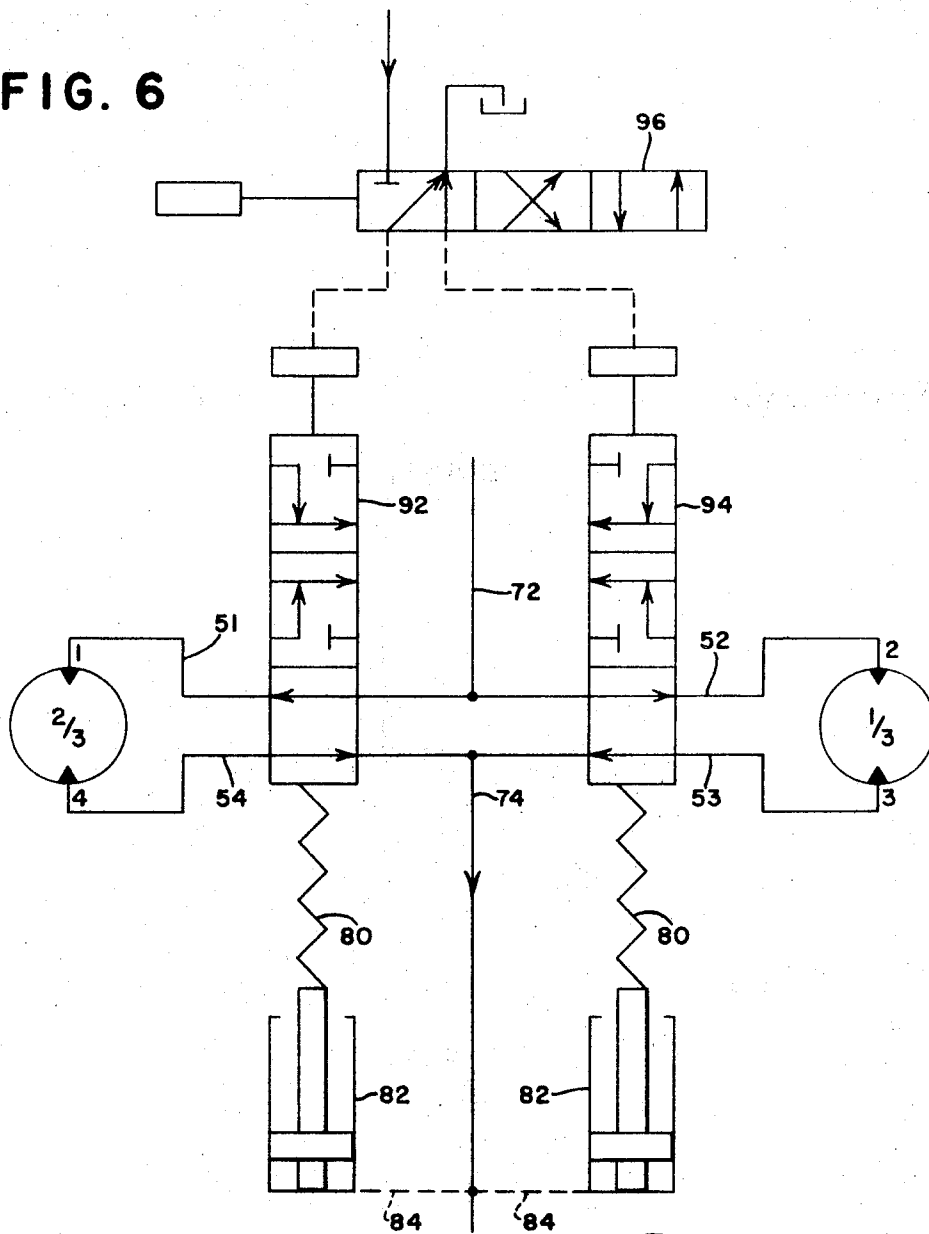


FIG. 7

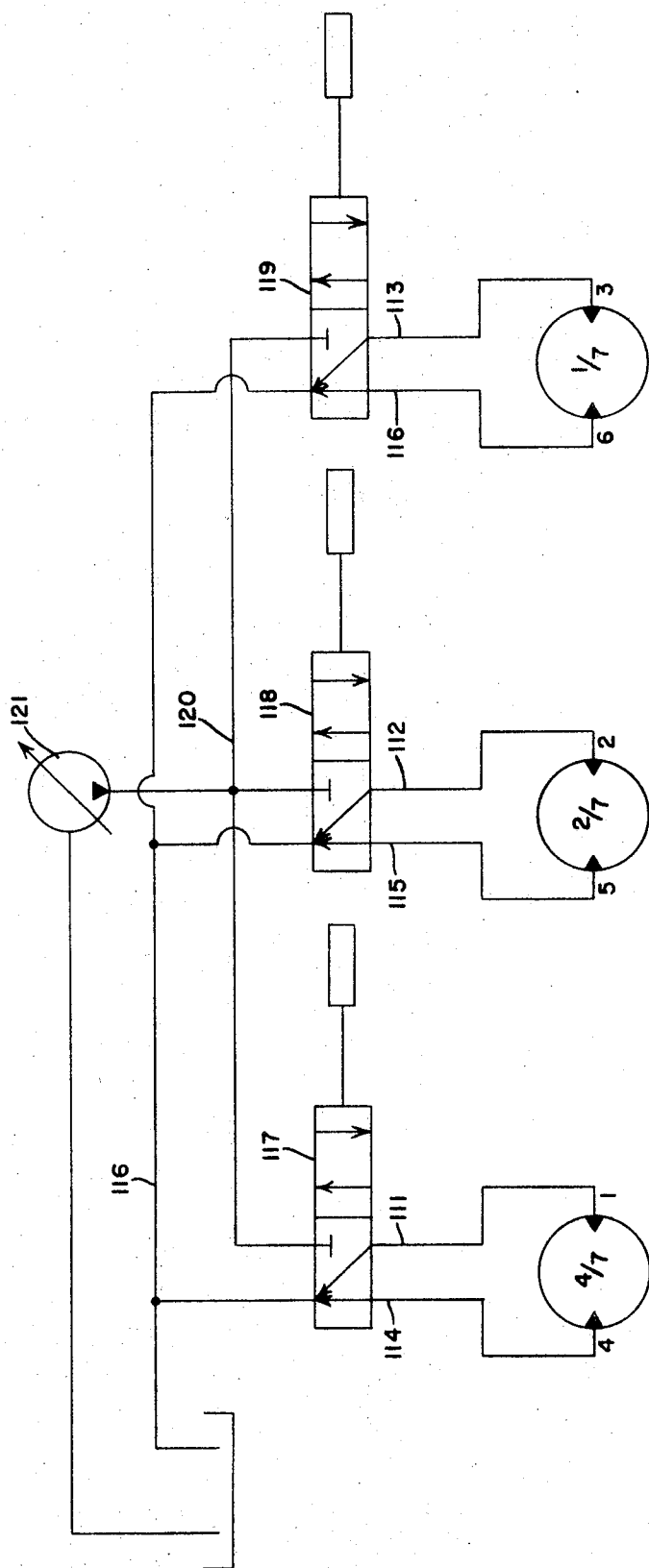


FIG. 8

## STEP VARIABLE DISPLACEMENT HYDRAULIC MOTOR

### BACKGROUND OF THE INVENTION

This invention relates to a rotary, hydraulic motor, and more particularly to a high torque, low speed hydraulic motor of the type having a number of radial pistons having cam followers on their outer ends, which engage an annular generally sinusoidal cam surface so that the motor rotates in response to reciprocation of the pistons.

Generally, in such motors, each piston goes through a cycle for each lobe of the cam surface, which requires a relatively large number of cycles for each revolution of the motor, so that the motor has high torque, low speed characteristics. Such hydraulic motors, sometimes referred to as cam lobe motors, are relatively new, and have been used recently in some low speed, high torque applications, such as wheel motors for hydraulically driven vehicles.

### SUMMARY OF THE INVENTION

According to the present invention there is provided an improved radial piston cam lobe motor with a stepped variable displacement. More specifically, valve means are provided for such a motor so that the pistons will complete one cycle for each cam lobe, to give one displacement, or will idle on certain of the cam lobes, to give a different motor displacement.

According to one aspect of the invention, four different passages are provided in the housing and are sequentially connected to the cylinders for the radial pistons, and valve means are provided to connect alternate passages to the fluid pressure source and the return line to alternately pressurize and exhaust each cylinder as its piston moves along each cam lobe, or to alternately pressurize only one of the passages so that each piston goes through a working stroke only on alternate cam lobes.

Another feature of the invention resides in the provision of different size cam lobes in an alternating, repeating pattern around the cam surface, so that one displacement is provided when the pistons have a working stroke on each cam lobe, a second displacement is provided when the pistons are idle on one size cam lobe, and a third displacement is provided when the pistons are idle on a different size cam lobe. In addition, more than two different size cam lobes can be provided, and different combinations of working strokes for each piston can be achieved by appropriate valve means, so that a relatively large number of displacements can be provided.

Still another feature of the invention resides in provisions of valve means which will permit reverse rotation of the motor at said different motor displacements.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an axial section through the hydraulic motor, as viewed generally along the line 1—1 of FIG. 2.

FIG. 2 is a section of the motor as viewed generally along the line 2—2 of FIG. 1, on a slightly smaller scale.

FIG. 3 is a view of the valve manifold as viewed generally along the line 3—3 of FIG. 1.

FIG. 4 is a schematic illustration of the hydraulic circuit in which the motor is utilized.

FIG. 5 is a schematic illustration of an alternate design of the cam surface, which is laid out in a straight line rather than in a circle as in the actual motor.

FIG. 6 is a schematic illustration of the hydraulic circuit for the motor utilizing the cam surface shown in FIG. 5.

FIG. 7 is a schematic illustration similar to FIG. 5, but showing a third embodiment of the cam surface.

FIG. 8 is a schematic illustration of the hydraulic circuit for the motor utilizing the cam surface shown in FIG. 7.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention is embodied in a hydraulic motor having a housing, indicated generally by the numeral 10. The housing is formed by an annular member 12, an annular end plate 14, and an annular ring 16 coaxially clamped between the member 12 and the plate 14 by a plurality of axially extending bolts 18, forming a generally cylindrical chamber 20. The inner surface of the annular ring 16 is provided with a generally sinusoidal cam surface 22 having a relatively large number of cam lobes 24 extending radially into the chamber, the cam surface illustrated in FIG. 2 having 10 identical cam lobes at 36° intervals.

The right-hand end of the annular housing member 12 is closed by an end plate 26, which carries a bearing 28, aligned with a similar bearing 30 around the opening in the annular end plate 14. An axial output shaft 32 extends through the end plate 14 and is journaled in the bearings 28 and 30, the shaft 32 spanning the axial length of the housing.

Attached to the shaft 32 is a cylinder block or barrel 34 having a plurality of equiangularly spaced radially extending cylinders 36, the motor illustrated in FIGS. 1-4 having 12 cylinders spaced at 30° intervals. As is apparent, the outer ends of cylinders open into the chamber 20 and are provided with pistons 38, the outer end of each piston being provided with a pair of rollers 40, which are axially parallel to the motor shaft 32 and engage the cam surface 22. As is conventional in cam lobe motors, and as described in U. S. Pat. No. 3,511,131, also assigned to the assignee herein, reciprocation of the pistons while the rollers are in engagement with the cam surface causes the cylinder block 34 and consequently the output shaft 32 to rotate. A helical compression spring 42 within each cylinder 36 biases the respective piston 38 outwardly into engagement with the cam surface.

A passage 44 extends axially from the inner end of each cylinder 36 through the cylinder block 34 and a valve plate 46 secured to the end of the cylinder block, each passage 44 terminating in a valve port 48 on the radial valve face 50 of the valve plate, the respective valve ports 48 being spaced at 30° intervals around the valve face.

The annular housing member 12 is provided with four fluid passages 51, 52, 53, and 54, respectively, each of the passages extending in an axial direction and having their outer ends communicating with appropriate fittings (not shown) on the outer radial face of the member 12, while the inner ends of the passages extend inwardly in a radial direction and respectively communicate with annular grooves 55, 56, 57, and 58 around the inner periphery of the member 12. While only the passages 51 and 54 in the housing are fully illustrated

in FIG. 1, the passages 52 and 53 are schematically illustrated and are similar to the passages 51 and 54.

An annular valve manifold 60 is rigid with and mounted within the member 12 around the output shaft 32. The manifold 60 has 20 axially extending passages 61, which are equally spaced at 18° intervals and terminate at valve ports 62 on the radial end face 63 of the manifold 60 opposite the valve face 50 of the valve plate 46. The arrangement of the valve ports on the manifold is best seen in FIG. 3. Each passage 61 is connected to one of the grooves 55-58, the connection being in a sequential fashion so that five of the ports are connected to the passage 51, five of the ports are connected to the passage 52, etc. To more clearly illustrate the above arrangement, the ports connected to the passage 51 are labeled with the numeral 1, the ports connected to the passage 52 are labeled with the numeral 2, the ports connected to the passage 53 are labeled with the numeral 3, and the ports connected to the passage 54 are labeled with the numeral 4.

Three balance pistons 65 are mounted in each of the 10 manifold passages 61 connected to the alternate ports labeled with the numerals 1 and 2. The right-hand or end balance piston 65 bears against a thrust bearing 66 clamped to the shaft 32 by an end plate 68 bolted to the end of the shaft and bearing against the thrust bearings through the inner race of the bearing 28. A helical compression spring 70 is mounted on the shaft between the manifold and the thrust bearing and acts to exert an axial force on the manifold urging it toward the valve plate 46. As best described in said U. S. Pat. No. 3,511,131, the balance pistons act to counterbalance the force tending to separate the manifold and the valve plate, thereby preventing excessive leakage. The passages 53 and 54 are respectively connected to the spaces on opposite sides of the center balance piston by suitable radial passage means (not shown) so that the balance pistons are also effective during reverse operation of the motor.

The hydraulic circuit for the motor shown in FIGS. 1-3 is schematically shown in FIG. 4, and includes a pressure supply line 72 which is connected to a fluid pressure source in the conventional manner and a return line 74. As is also conventional, means are provided for reversing the flow to the motor, either by use of reversing valving or by use of an over-center variable displacement pump. As is apparent, the motor passage 51 is connected to the supply line 72 and the passage 54 is connected to the return line 74, so that all of the manifold ports labeled with the numeral 1 are always connected to the line 72 and all the ports labeled 4 are always connected to the return line 74. A pilot-operated control valve 76 is shiftable into three different positions wherein it respectively connects the passage 52 to the passage 51 and the passage 53 to the passage 54, as illustrated in FIG. 4, or connects the passages 52 and 53 to the passage 51 or to the passage 54.

The control pressure for the pilot valve is supplied through a two-position, manually-actuated valve 78, and, as is apparent, when the pilot line is connected to the reservoir as illustrated, the pilot valve 76 is maintained in the illustrated position by a spring 80. When the manual valve 78 is shifted to pressurize the pilot line, the valve 76 shifts against the bias of the spring 80 to its lowermost position, wherein it connects the passages 52 and 53 to the passage 54. The spring 80 is mounted on the piston of a hydraulic cylinder 82,

which is connected by a pilot line 84 to the passage 54, so that when the passage 54 is pressurized during reverse operation of the motor, the piston shifts upwardly. When this occurs, and when the manual valve 78 is shifted to pressurize the pilot valve 76, the valve 76 is not allowed to shift completely downwardly, but rather is stopped by the extended cylinder 82 so that the valve shifts only to its intermediate position wherein the passages 52 and 53 are connected to the passage 51. Thus, the passages 52 and 53 are connected to the reservoir whenever the manual valve 78 is shifted to pressurize the pilot valve 76, regardless of whether the motor is being operated in forward or reverse.

In operation, as described in greater detail in U. S. Pat. No. 3,511,131, the manifold ports 62 are so related to the valve ports 48 that pressurization of the alternate manifold ports 62 will cause reciprocation of the pistons 38, and the valve ports are so related to the cam surface that the reciprocation of the pistons will cause rotation of the cylinder block 34 and consequently the output shaft 32. This can best be seen in FIGS. 2 and 3, where the 3 o'clock piston 38 is at the top of the cam lobe 24 when the valve port 48 is in transition between the pressurized manifold port labeled with the numeral 1 and the exhaust manifold port labeled with the numeral 3. Similarly, the piston 38 in the 6 o'clock position is in its transitional phase, while the piston in the 4 o'clock position is connected to the pressurized port identified by the numeral 2 and the piston in the 5 o'clock position is connected to the pressurized port identified by the numeral 1, both of said pistons being in their working stroke and on the slope of the cam to cause counterclockwise rotation of the cylinder barrel 34. On the other hand, the piston in the 7 o'clock position is connected to a valve port labeled with the numeral 4, which is connected to the return line, so that the piston is shown during its return stroke. Thus, in FIG. 2 the pistons shown in the 4, 5, 10, and 11 o'clock positions are in their working stroke, while the pistons shown in the 1, 2, 7, and 8 o'clock positions are in their return strokes, and the other four pistons are in transitional phases.

The above, of course, assumes that the valve 76 is in the position illustrated in FIG. 4 wherein all ports labeled with the numerals 1 and 2 are connected to the pressure supply line 72. If the valve 78 is shifted to supply pilot pressure to the valve 76, the valve 76 connects the passages 52 and 53 to the passage 54, so that only the ports labeled with the numeral 1 are connected to the pressure source, while the remaining ports are connected to the return line. In such a case, every other piston would be idling. Thus, in FIG. 2, the piston shown in the 4 o'clock position would be connected to the return line rather than the pressurized line and would be idling. Therefore, in FIG. 2 the only pistons that would be in their working stroke would be the pistons in the 5 and 10 o'clock positions. This of course, cuts the motor displacement in half and consequently the torque, while doubling the motor speed for a given flow rate.

As previously described, the flow can be reversed, with the valve 76 in the position shown in FIG. 4, so that the motor can be driven in reverse at full displacement. As previously described, the valve 76 can be shifted into the intermediate position wherein the passages 52 and 53 are connected to the passage 51, so

that the motor can be operated at one-half displacement in reverse.

A three-speed motor is schematically illustrated in FIGS. 5 and 6, the motor having a cam surface 86 similar to the cam surface 82 except that it has alternating small and large cam lobes 88 and 90 around the entire cam surface. The shape of the cam surface as shown in FIG. 5, the small cam lobes 88 having one-half the height or radial dimension of the large cam lobes 90, so that there are five large lobes and five small lobes. The cam surface is so related to the manifold valve ports 62 that the ports identified by the numerals 1 and 4 are associated with the large cam lobes 90, while the ports identified by the numerals 2 and 3 are associated with the small cam lobes 88. Thus, as shown in FIG. 6, the cylinders connected to the valve ports 1 and 4 produce two-thirds of the motor displacement, while the other cylinders produce the remaining one-third, as opposed to the previously described embodiment where each group of cylinders produce one-half of the displacement.

The flow to and from the passages 51, 52, 53, and 54 is controlled by a pair of pilot-operated control valves 92 and 94, which are identical to the previously described pilot-operated valve 76. The pilot line pressure is controlled by a three-position, manually-actuated valve 96, which is adapted to supply pilot pressure to either the valve 92 or the valve 94, or to connect both of said valves to the reservoir, as shown in FIG. 6. As previously described, the valves 92 and 94 are biased into the position shown by a spring 80, the preload of which is controlled by a cylinder 82 actuated through a pilot line 84, so that the pilot-operated valve will shift only to its intermediate position when the return line 74 is pressurized for reverse operation.

In operation, when the valve 96 is positioned as illustrated to drain both pilot lines, the valves 92 and 94 are in the position illustrated wherein the supply line 72 is connected to the passages 51 and 52 and the return line 74 is connected to the passages 53 and 54, providing a full motor displacement as previously described.

When the manually actuated valve 96 is shifted to the left into an intermediate position to supply pilot pressure to the right-hand control valve 94, the valve 94 shifts downwardly to connect the passages 52 and 53 to the return line 74, but only the passage 51 and the corresponding manifolds labeled with the numeral 1 are connected to the pressure supply line 72. Since pressurization of the number 1 manifold ports causes the pistons to reciprocate only on the large cam lobes 90, the motor will have two-thirds of the previously described full displacement. If the valve 96 is shifted all the way to the left to supply pilot pressure to the left-hand valve 92, the pressure supply line will only be connected to the passage 52 and consequently the number 2 manifold ports only. Since the number 2 ports cause reciprocation of the pistons only on the small cam lobes 88, which cause only one-half the displacement of the large cam lobes, the motor will have only one-third of its full displacement. Thus, the motor will produce three different torques and three different speeds for a given flow rate.

As is apparent, the different speeds can be achieved in either forward or reverse as previously described.

A further embodiment of the invention is schematically shown in FIGS. 7 and 8 wherein seven different motor displacements are provided. The motor has a cam surface 100 somewhat similar to the previously de-

scribed cam surfaces, except that the cam surface has four small cam lobes 101, four intermediate size cam lobes 102, which are twice the height of the cam lobes 101, and four large cam lobes 104 which are twice the height of the lobes 102 or four times the height of the lobes 101. Thus, a total of twelve cam lobes are provided, so that 24 ports are necessary on the valve manifold, the ports being arranged in an alternating repeating pattern similar to the ports described in FIG. 3, except that six different ports, identified by the numerals 1-6 in FIG. 8, are provided, the six different ports respectively being connected to six different motor housing passages 111, 112, 113, 114, 115, and 116. The passages 114, 115, and 116 are always connected to a return line 116 by control valves 117, 118, and 119, which are respectively shiftable to connect the passages 111, 112, or 113 to the return line 116 or a fluid pressure line 120 from a pump 121. Of course, a different number of pistons would also be required.

When the valves 117, 118, and 119 are in the position illustrated, all of the supply ports are connected to the reservoir so that the motor is in neutral. If the right-hand control valve 119 is shifted to pressurize the passage 113, and consequently the number 3 manifold ports, the pistons will reciprocate only on the small cam lobe 101, which gives only one-seventh of the full displacement. Similarly, if only the middle control valve 118 is shifted to pressurize only the number 2 ports, the pistons will reciprocate only on the medium-sized cam lobes 102, to give two-sevenths of the total displacement, or double the previously described displacement. However, if both the control valves 118 and 119 are shifted to pressurize both the number 2 and number 3 ports, the displacement will be the sum of the previously described displacement or three-sevenths of the total displacement. Then, if only the left-hand control valve 117 is shifted, pressurizing only the number 1 ports, the pistons will act only on the large cam lobe 104, to provide four-sevenths of the total displacement. To obtain five-sevenths of the total displacement, both the valve 117 and the valve 119 are shifted so that the pistons acts on both the small lobes and the largest cam lobes 104, while applying pressure to both the number 1 and number 2 valve ports causes the pistons to act on the medium cam lobes 102 and the large lobes 104 to give six-sevenths of the total displacement. For full motor displacement, all three valves 117, 118, and 119 are shifted to pressurize the number 1, number 2, and number 3 ports so that the pistons act on all three cam lobes. Thus, seven different displacements can be achieved in equal gradients. Obviously, the size of the increments could be varied by varying the shape of the cam. Also, reverse operation could be positioned in a similar manner as that previously described.

We claim:

1. A hydraulic motor comprising: a housing forming a generally cylindrical chamber and including a manifold having at least four passages extending to the manifold and terminating in manifold ports; an annular cam surface on the inner circumferential surface of said chamber and including a plurality of cam lobes disposed at equiangular intervals around said surface; a cylinder block mounted within the chamber for rotation relative to the housing and having a plurality of radially extending cylinders, each cylinder having an associated valve port sequentially communicating with the manifold ports during rotation of the block relative

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to the housing for sequentially connecting the passages to the valve ports; a piston for reciprocation in each cylinder in response to alternate pressurizing and exhausting of the cylinders and having cam follower means engageable with the cam surface to cause relative rotation between the cylinder block and the housing in response to reciprocation of the pistons; reversible fluid pressure and fluid return lines; and control valve means external of the housing and shiftable between a first position, wherein it connects two of the passages to the pressure line and two of the passages to

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the return line to establish a first motor displacement, a second position wherein it connects one of the passages to the pressure line and the other passages to the return line to establish an alternate motor displacement, and a third position when said pressure and return lines are reversed for reverse operation of the motor wherein a different one of said passages is connected to the pressure line and the other three are connected to the return line to provide an alternate displacement in reverse.

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