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(54) **AXIAL PISTON PUMP/MOTOR WITH CLUTCH AND THROUGH SHAFT**

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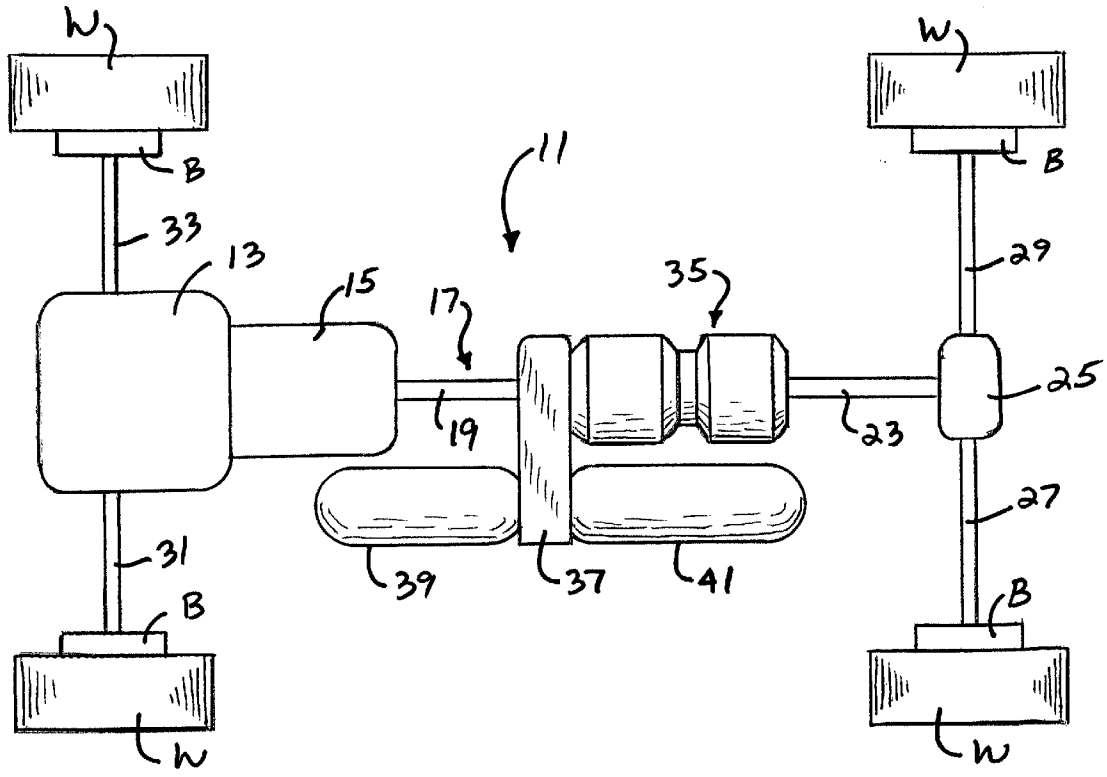
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(57) **ABSTRACT**

A hydrostatic pump-motor unit (**35**) including a clutch assembly (**43**) and a pump-motor portion (**45**) disposed within a housing assembly (**51,55,57**). An intermediate drive shaft (**21**) extends through the entire axial extent of the unit (**35**) and is surrounded by a hollow shaft member (**63**). The housing assembly (**51,55,57**) supports the drive shaft (**21**) by means of a pair of bearing sets (**67,71**), and the hollow shaft member (**63**) is supported relative to the housing assembly by means of a pair of bearing sets (**75,79**). The pump-motor portion (**45**) includes an axial piston cylinder barrel (**115**) surrounding the shaft member (**63**) and splined thereto. The clutch assembly (**43**) is operable to selectively clutch and de-clutch the drive shaft (**21**) and the hollow shaft member (**63**). Having the drive line extend through the pump-motor unit (**35**) substantially improves the packaging of the overall drive system.



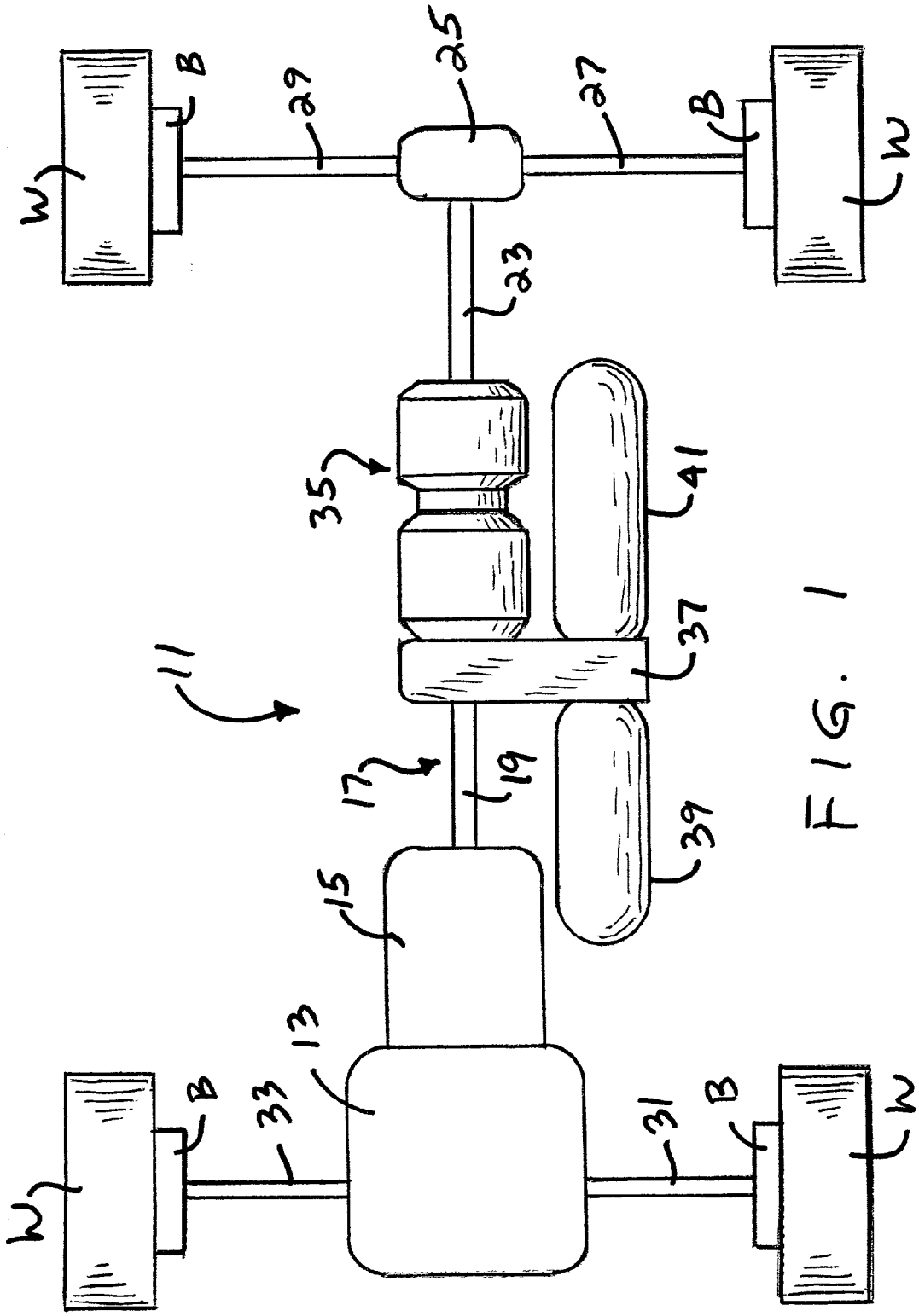


FIG. 1

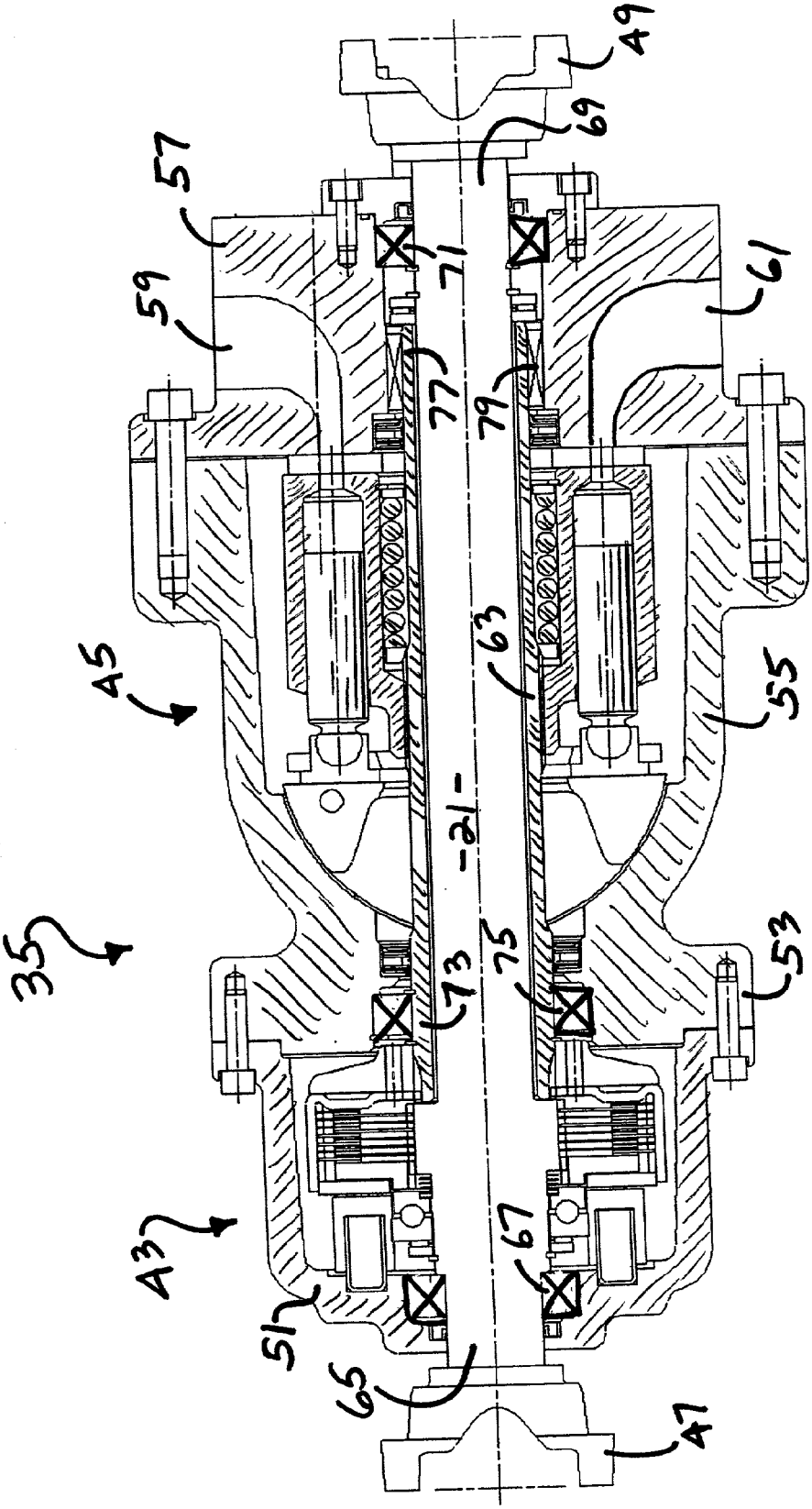


FIG. 2

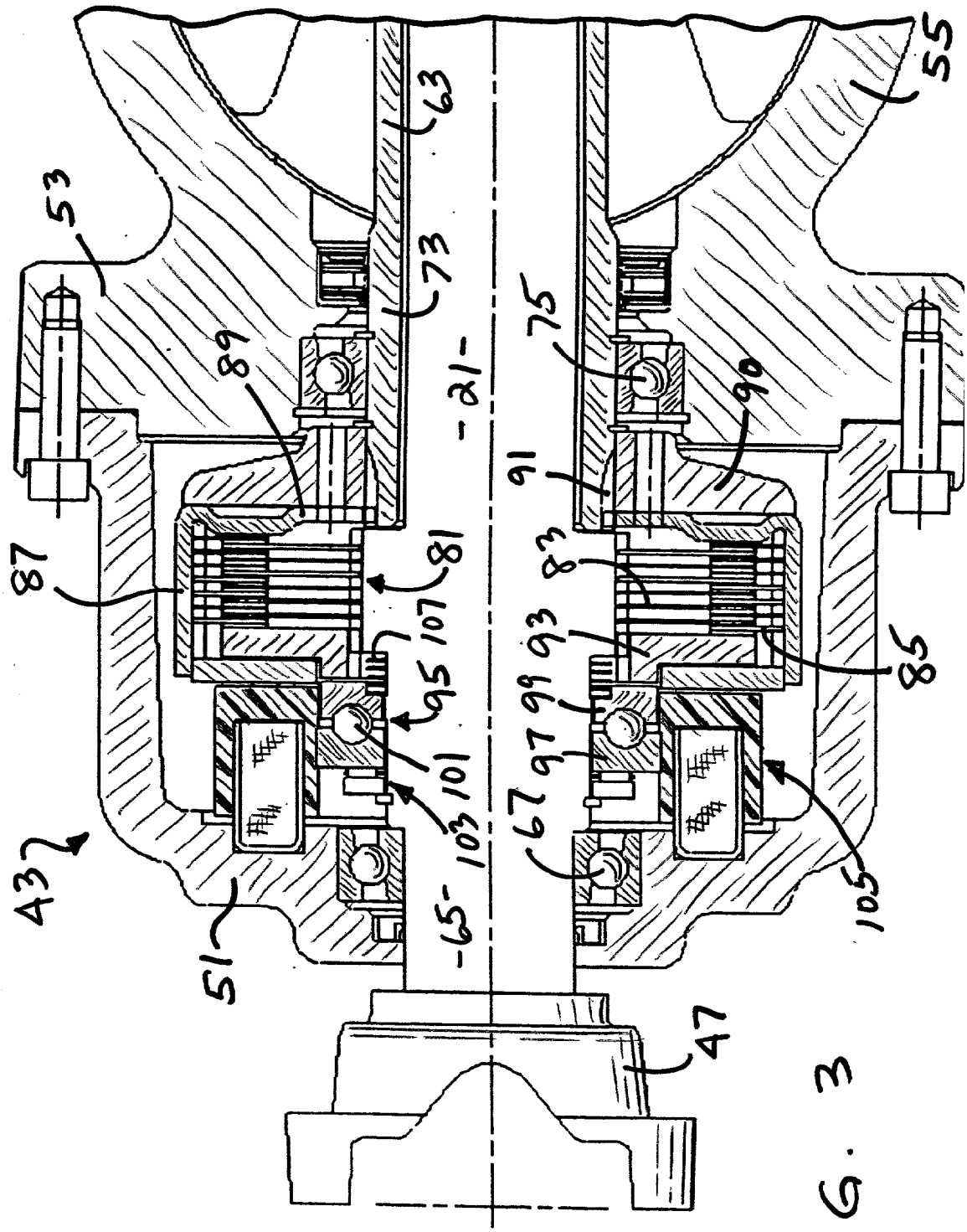

55
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53
73
75
89
-21-
90
91
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81
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101
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105
43
51
-65-
47

FIG. 3

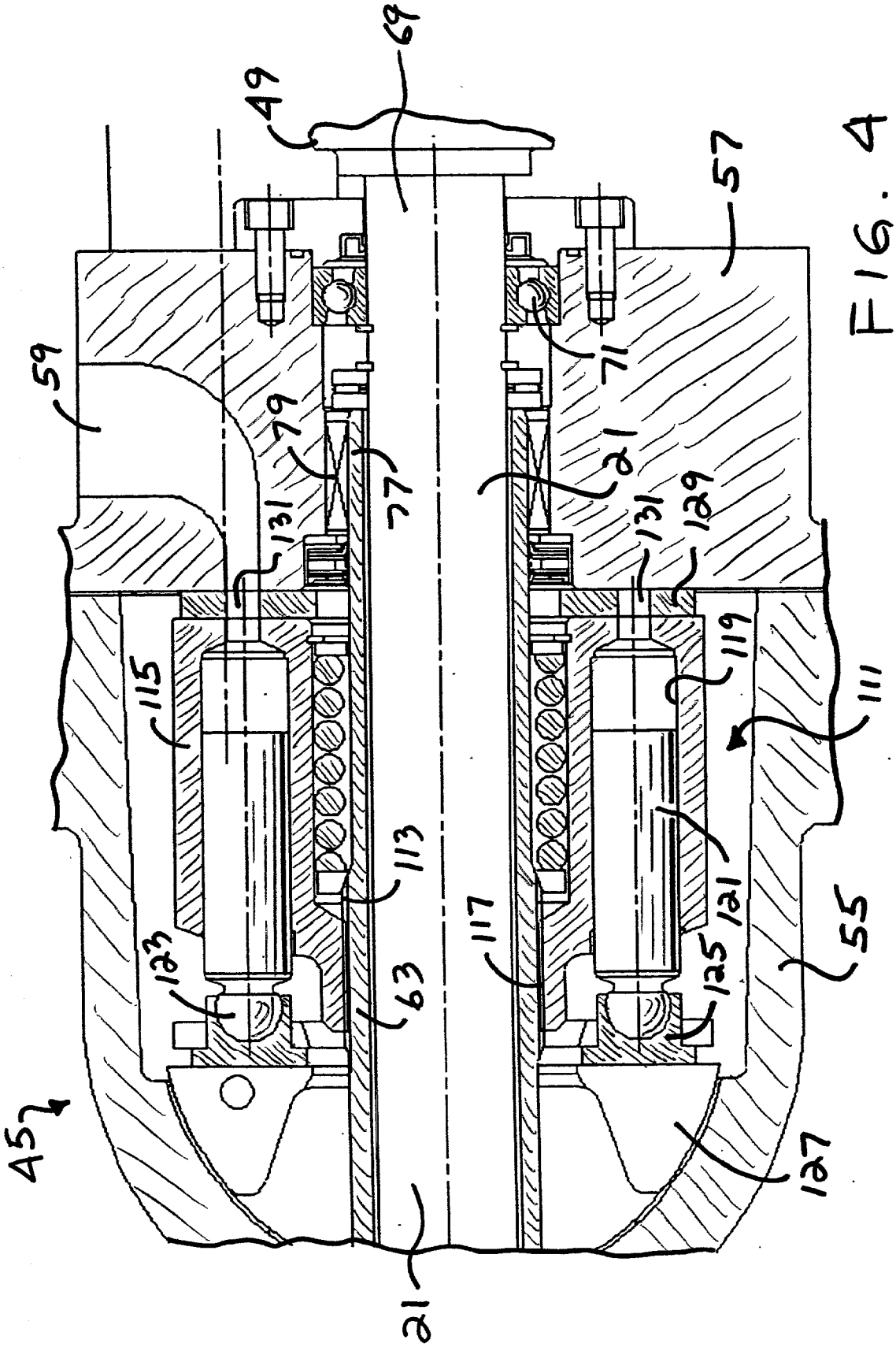

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59
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79
77
21
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129
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119
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123
125
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45
127
21

FIG. 4

AXIAL PISTON PUMP/MOTOR WITH CLUTCH AND THROUGH SHAFT

BACKGROUND OF THE DISCLOSURE

[0001] The present invention relates to a hydrostatic pump-motor unit, and more particularly, to such a unit which is intended for use in a vehicle drive system which also includes a mechanical transmission and drive line. As used herein, the term "drive line" will be understood to mean and include, but not be limited to, a conventional rear wheel drive type of prop shaft.

[0002] The hydrostatic pump-motor unit of the present invention may be used in connection with a variety of vehicle drive systems, but it is especially adapted for use in a vehicle drive system of the type in which torque is transmitted to the drive wheels from a mechanical transmission during part of the operating cycle, and from the hydrostatic unit during the remainder of the operating cycle, and the invention will be described in connection with such a system. It should be understood that for purposes of the present invention, the vehicle drive system may involve the transmission of torque from the hydrostatic unit to the drive wheels in lieu of torque from the mechanical transmission, or in addition to such torque.

[0003] More specifically, the present invention is especially advantageous when utilized as part of a vehicle drive system having regenerative braking capability, although it should be clearly understood that the present invention is not so limited. In such a system, and assuming by way of example only that the vehicle is of the rear wheel drive type, the primary drive torque is transmitted from the engine through the conventional mechanical transmission and then by means of a conventional drive line to the rear drive wheels. During braking (i.e., at any time during a "deceleration-acceleration" cycle,) the braking energy is transmitted to the hydrostatic pump-motor unit, which is then acting as a pump, and charges a high pressure accumulator. When the vehicle is subsequently accelerated, the hydrostatic pump-motor unit operates in a motoring mode, and the high pressure stored in the accumulator is then communicated to the pump-motor unit, and its output torque is transmitted to the vehicle drive line.

[0004] It will be understood by those skilled in the art that there are several reasons why the present invention is especially suited for use in a drive system of the type described above which has regenerative braking capability. First, such a system typically includes not only the high pressure accumulator referred to, but also a low pressure accumulator, and the presence of these two accumulators adds substantial size to the overall drive system, thus making packaging of the system especially challenging.

[0005] Secondly, a hydrostatic pump-motor unit which is being used in a system of the type described above needs to include the capability of being selectively clutched to, or de-clutched from, the main vehicle drive line, which further complicates the packaging of the entire system.

BRIEF SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide an improved hydrostatic pump-motor unit for use in a vehicle drive system which overcomes the problems described above.

[0007] It is a more specific object of the present invention to provide such an improved pump-motor unit which makes it possible to substantially reduce the overall packaging size of the drive system, as well as the complexity of the drive system.

[0008] The above and other objects of the invention are accomplished by the provision of an improved hydrostatic pump-motor unit adapted for use on a vehicle having a drive system including an engine, a transmission, and a drive line operable to transmit driving torque from the transmission to a drive axle. The hydrostatic pump-motor unit defines a housing including a fluid inlet port and a fluid outlet port, the housing defining a pumping cavity and disposed therein, a rotatable cylinder barrel defining a plurality of generally axially oriented cylinders, and a piston disposed for a reciprocable movement in each cylinder. The unit includes a swashplate disposed adjacent the barrel and having the pistons in engagement with the swashplate as the cylinder barrel rotates.

[0009] The improved hydrostatic pump-motor unit is characterized by the unit having bearings adapted to fix the location of the housing relative to the drive line. A hollow, generally cylindrical shaft member is adapted to surround the drive line and is surrounded by, and non-rotatably fixed relative to, the cylinder barrel. A clutch assembly is disposed adjacent a first end of the shaft member and includes a first clutch member adapted to be fixed for rotation with the drive line and a second clutch member fixed for rotation with the shaft member. A clutch assembly has a first condition in which the first and second clutch members are out of driving engagement, and a second condition in which the first and second clutch members are in driving engagement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** is a schematic view of a vehicle drive system of the type with which the pump-motor unit of the present invention is especially well suited.

[0011] **FIG. 2** is an axial cross-section of one embodiment of the entire hydrostatic pump-motor unit of the present invention.

[0012] **FIG. 3** is an enlarged, fragmentary axial cross-section similar to **FIG. 2**, showing primarily the clutch assembly of the present invention.

[0013] **FIG. 4** is an enlarged, fragmentary axial cross-section showing only the pump-motor portion, and on a slightly smaller scale than **FIG. 3**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0014] Referring now to the drawings, which are not intended to limit the invention, **FIG. 1** illustrates a vehicle drive system of the type with which the present invention is especially well suited. The vehicle shown schematically in **FIG. 1** has four drive wheels W, although it should be understood that the present invention is not limited to a vehicle having four wheel drive, but could also be used with a vehicle having only two wheel drive, and in that case, the two drive wheels could be either rear drive wheels or front drive wheels. Operably associated with each of the drive wheels W is a conventional type of wheel brake B, the

details of which form no part of the present invention, and the wheel brakes B will be referred to only briefly hereinafter.

[0015] The vehicle includes a vehicle drive system, generally designated **11**, which includes a vehicle engine **13** and a transmission **15**. It should be understood that the particular type of engine **13** and transmission **15** and the construction details thereof form no part of the present invention and therefore, will not be described further herein.

[0016] Extending rearward from the transmission **15** is a drive line, generally designated **17**. In the subject embodiment and by way of example only, the drive line **17** includes a forward drive shaft **19**, an intermediate drive shaft **21** (see **FIG. 2**), a rearward drive shaft **23**, an inter wheel differential **25** and left and right rear axle shafts **27** and **29**.

[0017] The drive system **11**, in the subject embodiment, also includes left and right forward axle shafts **31** and **33**, respectively. Referring still primarily to **FIG. 1**, in addition to the "mechanical" elements already described and which are fairly conventional, the drive system **11** also includes a hydrostatic pump-motor unit, generally designated **35**, and disposed forwardly of the pump-motor unit **35** is a valve manifold **37**. Attached to a forward portion of the valve manifold **37** is a low pressure accumulator **39**, and attached to a rear portion of the valve manifold **37** is a high pressure accumulator **41**. It should be understood that the valve manifold **37** and the accumulators **39** and **41** are not essential features of the present invention, and therefore, the construction details of each is not illustrated or described herein. Instead, the general function and operation of each will be described briefly, but only to the extent necessary to describe the several operating modes of the pump-motor unit **35** of the present invention.

[0018] Referring primarily to **FIG. 2**, the pump-motor unit **35** will be described in somewhat more detail now, and even greater detail in connection with the description of **FIGS. 3 and 4**. The pump-motor unit **35** includes a clutch assembly, generally designated **43** and a pump-motor portion, generally designated **45**. In accordance with an important aspect of the invention, it may be seen that the intermediate drive shaft **21** extends completely through the hydrostatic pump-motor unit **35** and has, at its forward end, a universal joint coupling (only partially shown) **47** for connection to the forward drive shaft **19**. Similarly, the intermediate drive shaft **21** has, at its rearward end, a universal joint coupling **49**, for connection to the rearward drive shaft **23**.

[0019] Referring still primarily to **FIG. 2**, the clutch assembly **43** includes a clutch housing **51** which is bolted to a forward flange **53** of a pump-motor housing **55**. Bolted to the rearward surface of the housing **55** is a port housing **57** which defines an inlet port **59** and an outlet port **61**. Typically, the inlet port **59** and outlet port **61** would both be plumbed to the valve manifold **37**. Surrounding a major portion of the axial length of the intermediate drive shaft **21** is a hollow, generally cylindrical shaft member **63**, having its inside diameter radially spaced apart from the outside diameter of the intermediate drive shaft **21**.

[0020] In accordance with another important aspect of the invention, a forward portion **65** of the intermediate drive shaft **21** is rotatably supported, relative to the clutch housing **51**, by means of a ball bearing set **67** while a rearward portion **69** of the intermediate drive shaft **21** is rotatably supported relative to the port housing **57** by means of a ball bearing set **71**. The shaft hollow member **63** includes forward portion **73** which is rotatably supported relative to the pump-motor housing **55** by means of a ball bearing set **75**, while a rearward portion **77** of the shaft member **63** is rotatably supported relative to the port housing **57** by means of a roller bearing set **79**. It should be noted that all of the bearing sets **67**, **71**, **75** and **79** are shown only schematically in **FIG. 2**.

[0021] Referring now primarily to **FIG. 3**, the clutch assembly **43** will be described in some detail. Disposed within the clutch housing **51** is an enlarged, externally splined portion **81** of the intermediate drive shaft **21**. Surrounding the portion **81** is a clutch pack, including a set of internally splined clutch disks **83**, and interleaved with the disks **83** is a set of externally splined clutch disks **85**, the clutch disks **85** being in splined engagement with a clutch cage **87**. The clutch cage **87** surrounds the clutch pack, and includes a radially extending portion **89** which is in splined engagement at its inner periphery with a set of external splines **91** formed about the forward portion **73** of the shaft member **63**. Thus, the clutch cage **87** is fixed to rotate with the shaft member **63**. Disposed immediately adjacent the radially extending portion **89** is a reaction member **90**, preferably fixed to the portion **89**, the primary function of the reaction member **90** being to provide rigidity to the entire clutch cage **87** whenever the clutch pack is loaded axially (engaged).

[0022] Disposed immediately adjacent the clutch pack (clutch disks **83** and **85**) is a clutch apply piston **93**, and disposed forwardly (to the left in **FIG. 3**) of the piston **93** is a ball ramp actuator **95**, including an input ramp plate **97**, an output ramp plate **99**, and a plurality of cam balls **101**. As will be understood by those skilled in the art, the input ramp plate **97** has its axial position, relative to the intermediate drive shaft **21**, fixed by some form of axial retention and bearing arrangement, generally designated **103**, the details of which are not essential features of the invention.

[0023] Disposed radially outwardly of the ball ramp actuator **95** is an electromagnetic coil assembly, generally designated **105**, the function of which is to receive an electrical input signal, such as from the vehicle microprocessor, and initiate actuation of the ball ramp actuator **95**. This is accomplished by the coil assembly **105** generating an electromagnetic field which is intersected by the input ramp plate **97** such that, when the coil assembly **105** is energized, rotation of the input ramp plate **97** is retarded somewhat which, in turn, causes ramping of the cam balls **101** on the ramp surfaces defined by the ramp plates **97** and **99**, thus causing the output ramp plate **99** to be forced rearward (to the right in **FIG. 3**). Such rearward movement of the output ramp plate **99** overcomes the bias, in a forward direction, caused by a spring member **107**, so that the output ramp plate **99** biases the clutch apply piston **93** rearward to load the clutch disks **83**, **85**. When such loading is applied to the clutch disks **83**, **85**, the shaft member **63** will thereafter rotate at the same speed as the intermediate drive shaft **21**. When there is no such loading on the clutch disks **83**, **85**, the shaft member **63** remains substantially stationary within the stationary pump-motor housing **55**.

[0024] It should be understood by those skilled in the art that, although the clutch assembly **43** is illustrated as includ-

ing a friction disk and ball ramp actuator type of clutch assembly, the present invention is not so limited. For example, the clutch assembly could be friction disks electro-hydraulically actuated, or could comprise a mechanical dog clutch (and a synchronizer, if necessary) actuated electro-mechanically, or could be whatever other known type of clutch and actuator meets the particular size, cost and operating criteria for the particular vehicle drive line installation.

[0025] Referring now primarily to **FIG. 4**, the pump-motor portion **45** will be described in some detail, recognizing that the construction details of the pump-motor portion **45** are not, in general, essential features of the present invention. The pump-motor housing **55** defines an internal cavity **111**. As was best seen in **FIG. 2**, the hollow shaft member **63** extends into and axially through the entire extent of the internal cavity **111**. The shaft member **63** includes a set of external splines **113**, and disposed about that region of the shaft member **63** is a cylinder barrel **115** which includes a set of internal splines **117** in splined engagement with the external splines **113**. Thus, the cylinder barrel **115** is non-rotatable relative to the shaft member **63** but in accordance with a primary aspect of the present invention, the cylinder barrel **115** surrounds the shaft member **63**, and therefore, also surrounds the intermediate drive shaft **21**.

[0026] The cylinder barrel **115** defines a plurality of cylinder bores **119**, and disposed for reciprocating motion within each cylinder bore **119** is a piston **121**. Each piston **121** includes a generally spherical head **123** which is received within a piston shoe (or "slipper") **125**. The piston shoes **125** are retained in contact with a swashplate **127** in a manner generally well know to those skilled in the art and which forms no part of the present invention. The swashplate **127** is shown in **FIG. 4**, by way of example only, as being of the "swash and cradle" type although, those skilled in the art will understand that the swashplate **127** could also be of the trunnion type. In the subject embodiment, as shown in **FIG. 4**, the swashplate **127** is shown in its neutral (zero displacement) position because the pump-motor portion **45** is of the variable displacement type although, within the scope of the present invention, it would be possible for the pump-motor portion **45** to be of the fixed displacement type.

[0027] Those skilled in the art of drive systems of the type shown in **FIG. 1** will understand that for the pump-motor portion **45** to be used in that type of drive system, it would be preferred that the pump-motor portion be of the variable displacement type. However, the particular mechanism by which the displacement of the swashplate **127** may be varied, from the neutral position shown in **FIG. 4** toward a maximum displacement position in either direction therefrom, is well know to those skilled in the art, does not form an essential part of the invention, and will not be described herein. It is believed to be sufficient for purposes of this specification to merely point out that the displacement of the swashplate **127** would typically be varied by means of a piston and servo-type arrangement, in response to variations in a control pressure, which would typically be communicated to the pump-motor portion **45** from the valve manifold **37**.

[0028] At the rearward end of the cylinder barrel **115** is a valve plate **129** which defines a plurality of inlet and outlet ports **131**, by means of which the cylinder bores **119** are in cyclical communication with the inlet port **59** and with the outlet port **61**, in a manner well know to those skilled in the art.

[0029] Although the use of the pump-motor unit **35** of the present invention in the drive system **11** shown in **FIG. 1** is not an essential feature of the invention, it will be described briefly hereinafter to explain further the structure, function, and some of the benefits of the present invention. During "normal" operation of the drive system, i.e., when the vehicle is travelling along the highway at a generally constant velocity, no signal is being transmitted to the electromagnetic coil assembly **105** which is capable of energizing the coil **105** which, therefore, is in its "OFF" condition. With the coil assembly **105** in its OFF condition, the ball ramp actuator **95** is in its centered, neutral condition, under the influence of the spring member **107**, and the clutch apply piston **93** has no substantial axial load applied thereto. With no load on the apply piston **93**, the clutch disks **83** and **85** are not loaded into engagement but instead are in a "disengaged" condition, such that no torque is being transmitted from the intermediate drive shaft **21** to the hollow shaft member **63**. In this disengaged condition, the shaft member **63** and the cylinder barrel **115** are able to remain stationary within the pump-motor housing **55**, and the swashplate **127** remains in its neutral position shown in **FIG. 4**.

[0030] In the disengaged condition described above, the drive system **11** operates in a conventional manner, i.e., drive torque from the engine **13** is transmitted by the transmission **15**, and the drive line **17** to the inter-wheel differential **25**, and from there, by means of the left and right rear axle shafts **27** and **29** to the rear drive wheels W. In this disengaged mode of operation, the drive system **11** operates in substantially the same manner as it would if the pump-motor unit **35**, the valve manifold **37** and the accumulators **39** and **41** were not present.

[0031] When it is necessary for the vehicle to decelerate, and the operator begins to depress the vehicle brake pedal, the initial movement of the brake pedal (not shown herein) results in a signal being communicated to both the valve manifold **37** and to the coil assembly **105**, such that two things occur. The first is that the coil assembly **105** is energized, causing ramp-up of the ball ramp actuator **95** and engagement of the clutch disks **83** and **85**, in the manner described previously, such that the hollow shaft member **63** is now fixed to rotate with the intermediate drive shaft **21**. The second result of the brake pedal being depressed is that a signal is received at the valve manifold **37** which then communicates an appropriate control pressure to vary the displacement of the swashplate **127**, and preferably in the system shown, the angle and direction of displacement of the swashplate **127** would correspond generally to the amount of braking "effort" applied by the vehicle operator.

[0032] As a result of the above-described "engagement" operation, the pump-motor portion **45** is now being driven by the drive line **17** and is acting as a pump, such that high pressure fluid is pumped out of the outlet port **61** to the valve manifold **37** and from there to the high pressure accumulator **41**, such that the kinetic energy of the moving vehicle is converted to hydraulic energy, and is "stored" within the accumulator **41**, as the vehicle gradually comes to a stop. Depending upon the amount of braking effort exerted by the

vehicle operator, the individual wheel brakes B may also be utilized in bringing the vehicle to a complete stop, although it is probably desirable in such systems to size the pump-motor unit **35** and high pressure accumulator **41** such that all normal braking operations are performed using only the hydraulic system, and the wheel brakes B are needed only in the case of an emergency.

[**0033**] When it is subsequently desired to accelerate the vehicle from a stop, such as by the operator depressing the accelerator pedal, an appropriate signal is communicated to the hydrostatic pump motor unit **35**, and specifically, to the valve manifold **37**. As a result of the signal indicating a need for vehicle acceleration, the valve manifold **37** communicates a control pressure to move the swashplate **127**"over-center" to an appropriate displacement in which the pump-motor portion **45** will now operate as a motor. In the "motoring" mode of operation, the valve manifold **37** will permit the high pressure fluid stored in the accumulator **41** to flow from the accumulator **41** through the valve manifold **37** to the inlet port **59**, and from there into the cylinder bores **119**. With pressurized fluid in the bores **119**, the cylinder barrel **115** is now being driven and that drive torque is transmitted to the shaft member **63**, and from there through the clutch disks **83** and **85** to the drive line **17**, and specifically, to the intermediate drive shaft **21**.

[**0034**] Thus, it may be seen that the novel arrangement of the intermediate shaft **21** and the pump-motor unit **35**, in accordance with the present invention, provides a greatly improved packaging of the drive system **11**, compared to the arrangement which would result from the use of the known, prior art axial piston pump and clutch assembly.

[**0035**] The invention has been described in great detail in the foregoing specification, and it is believed that various alterations and modifications of the invention will become apparent to those skilled in the art from a reading and understanding of the specification. It is intended that all such alterations and modifications are included in the invention, insofar as they come within the scope of the appended claims.

What is claimed is:

1. A hydrostatic pump-motor unit adapted for use on a vehicle having a drive system including an engine, a transmission, and a drive-line operable to transmit driving torque from said transmission to a drive axle; said hydrostatic pump-motor unit including a housing defining a fluid inlet port and a fluid outlet port, said housing defining a pumping cavity and disposed therein, a rotatable cylinder barrel defining a plurality of generally axially oriented cylinders, and a piston disposed for reciprocable movement in each cylinder, and a swashplate disposed adjacent said barrel and having said pistons in engagement with said swashplate as said cylinder barrel rotates; characterized by:

(a) said hydrostatic pump-motor unit having bearings adapted to fix the location of said housing relative to said driveline;

(b) a hollow, generally cylindrical shaft member adapted to surround said driveline and being surrounded by and non-rotatably fixed relative to said cylinder barrel; and

(c) a clutch assembly disposed adjacent a first end of said shaft member and including a first clutch member adapted to be fixed for rotation with said driveline, and a second clutch member fixed for rotation with said shaft member, said clutch assembly having a first condition in which said first and second clutch members are out of driving engagement, and a second condition in which said first and second clutch members are in driving engagement.

2. A hydrostatic pump-motor unit as claimed in claim 1, characterized by said drive-line including an intermediate driveshaft extending axially through the entire axial extent of said hydrostatic pump-motor unit, and including a forward portion and a rearward portion, said pump-motor unit including said bearings fixing the location of said housing relative to said forward and rearward portions of said intermediate driveshaft.

3. A hydrostatic pump-motor unit as claimed in claim 2, characterized by said hollow shaft member includes a second end, and said pump-motor unit further includes bearings rotatably supporting said first and second ends of said hollow shaft member relative to said housing.

4. A hydrostatic pump-motor unit as claimed in claim 1, characterized by said first clutch member comprises a friction disk and said second clutch member comprises a friction disk, and said clutch assembly further comprises an electromechanical actuator operable to move said friction disks between engaged and disengaged conditions in response to changes in response to an electrical input signal.

5. A hydrostatic pump-motor unit as claimed in claim 1, characterized by said housing enclosing both said cylinder barrel and said clutch assembly.

* * * * *