**PCT** WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

**(51) International Patent Classification 5 :** F04B 39/02, F04D 1/06 — A1

**(11) International Publication Number:** WO 93/18303

**(43) International Publication Date:** 16 September 1993 (16.09.93)

**(21) International Application Number:** PCT/US93/02340

**(22) International Filing Date:** 12 March 1993 (12.03.93)

**(30) Priority data:**
850,560 13 March 1992 (13.03.92) US

**(71) Applicant:** PNEUMO ABEX CORPORATION [US/US]; 3151 West 5th Street, Oxnard, CA 93030 (US).

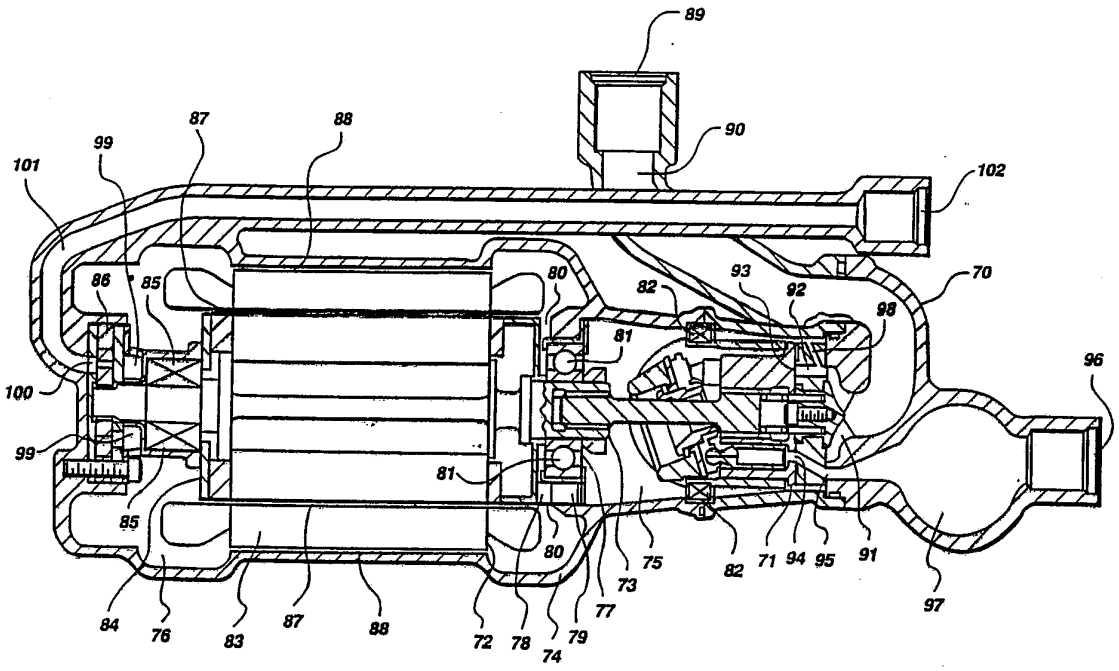
**(72) Inventors:** COAKLEY, Kim, L. ; 6043 Fremont Circle, Camarillo, CA 93012 (US). WARD, Elmer, F. ; 1041 La Limonar, Santa Ana, CA 92705 (US).

**(74) Agents:** BOND, Laurence, B. et al.; Trask, Britt & Rossa, P.O. Box 2550, Salt Lake City, UT 84111 (US).

**(81) Designated States:** JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

**Published**
*With international search report.*

**(54) Title:** WET ELECTRIC MOTOR DRIVEN PUMP




**(57) Abstract**

A wet electric motor driven pump (70) comprises a main pump (71), pumping a specified working fluid which is driven by a wet electric motor (72), operating submerged in the specified working fluid, and means for bleeding (98), prior to entry into the main pump (71), a portion of the specified working fluid from the total flow of the specified working fluid entering the wet electric motor driven pump (70) to form an auxiliary fluid flow, which auxiliary fluid flow is substantially all the fluid in which the wet electric motor (72) operates. The auxiliary fluid flow is also substantially all the fluid that is used to cool the wet electric motor (72) and to lubricate the wet electric motor (72) and main pump (71).

*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | |
|---|---|---|---|---|---|
| AT | Austria | FR | France | MR | Mauritania |
| AU | Australia | GA | Gabon | MW | Malawi |
| BB | Barbados | GB | United Kingdom | NL | Netherlands |
| BE | Belgium | GN | Guinea | NO | Norway |
| BF | Burkina Faso | GR | Greece | NZ | New Zealand |
| BG | Bulgaria | HU | Hungary | PL | Poland |
| BJ | Benin | IE | Ireland | PT | Portugal |
| BR | Brazil | IT | Italy | RO | Romania |
| CA | Canada | JP | Japan | RU | Russian Federation |
| CF | Central African Republic | KP | Democratic People's Republic of Korea | SD | Sudan |
| CG | Congo | | | SE | Sweden |
| CH | Switzerland | KR | Republic of Korea | SK | Slovak Republic |
| CI | Côte d'Ivoire | KZ | Kazakhstan | SN | Senegal |
| CM | Cameroon | LI | Liechtenstein | SU | Soviet Union |
| CS | Czechoslovakia | LK | Sri Lanka | TD | Chad |
| CZ | Czech Republic | LU | Luxembourg | TG | Togo |
| DE | Germany | MC | Monaco | UA | Ukraine |
| DK | Denmark | MG | Madagascar | US | United States of America |
| ES | Spain | ML | Mali | VN | Viet Nam |
| FI | Finland | MN | Mongolia | | |

# Wet Electric Motor Driven Pump

## BACKGROUND OF THE INVENTION

1. Field

The invention is in the field of fluid power units. More particularly, the invention relates to "wet" electric motor driven pumps.

2. State of the Art

Electric motor driven pumps are used to convert electric power into mechanical power by circulating fluid. A typical application of electric motor driven pumps is hydraulic power units that are commonly used to provide primary power or emergency or assistive power to an aircraft hydraulic system. One type of hydraulic power unit that is typically used to provide emergency or assistive power to an aircraft hydraulic system is an electric motor driven hydraulic pump. Prior art electric motor driven hydraulic pumps have typically been of two types, the "dry" type unit and the "wet" type unit. A dry electric motor driven hydraulic pump is configured such that the components of the electric motor portion of the unit, such as the rotor, stator, windings and usually some of the bearings which support the rotor, are surrounded by air. The electric motor of the dry type unit is either "air cooled" or "jacket cooled". The electric motor of the air cooled variety is cooled by circulating air through the casing in which the electric motor components are located. An example of an air cooled electric motor unit is disclosed in United States Patent No. 3,612,726 issued October 12, 1971 to Yowell. The electric motor of the jacket cooled variety is cooled by reducing the temperature of the air which is located within the electric motor casing by using a heat exchanger or cooling jacket. An example of a jacket cooled electric motor unit is the Vickers fluid-cooled AC motor pump, model no. MPEV3-056.

A wet electric motor driven hydraulic pump is configured such that the electric motor components, such as the rotor, stator and windings, the high pressure

hydraulic pump and internal flow pumps, if any, and the associated bearings which support these components are submerged in circulating hydraulic fluid which lubricates and cools these components.

Prior art wet electric motor driven hydraulic pumps are generally configured such that one or more electric motors drive one or more high pressure hydraulic pumps. In some prior art configurations the electric motor and hydraulic pump are integrated in a single housing, and in other prior art configurations the electric motor and hydraulic pump are modular and contained in separate housings wherein the hydraulic fluid circulates through both housings. Such prior art configurations include an in-line modular single pump/single motor configuration, such as the Pneumo Abex Corporation, Aerospace Division, AC Motor Pump model no. PMP 3V-3; an in-line integrated single pump/single motor configuration, such as the Pneumo Abex Corporation, Aerospace Division, AC Motor Pump model no. PMP 2V-7; and two pumps integrated into the motor rotors of two motors configuration, such as the Vickers Integrated Motorpump model no. MPEV3-040-2, which is the commercial embodiment of the invention disclosed in United States Patent No. 4,729,717 issued March 8, 1988 to Gupta.

A common feature of the prior art wet electric motor driven hydraulic pumps is the flow of substantially all the volume of the hydraulic fluid through the electric motor as a coolant and lubricant of the electric motor before the fluid is pumped by the high pressure hydraulic pump out of the unit as high pressure discharge or is pumped by internal flow pumps through and out of the unit as an auxiliary flow. In order to prevent cavitation of the high pressure hydraulic pump, which is downstream of the electric motor, a large volume of hydraulic fluid at a relatively high flow rate must pass through the electric motor cavity. To effectively cool the rotor and stator of the electric motor, hydraulic fluid must pass

through the clearance gap between the rotor and stator, which in some designs is as small as ten thousandths of an inch. In order to provide the required flow to prevent cavitation of the high pressure hydraulic pump, one or more relatively large bypass ports through which hydraulic fluid flows are required around the stator. Because the ratio of the cross-section areas of the large bypass ports to the cross-section area of the clearance gap between the rotor and stator is large, when the high pressure hydraulic pump is discharging little or no flow, the majority of the hydraulic fluid passes through the large bypass ports and not through the clearance gap between the rotor and stator. Therefore, optimum cooling of the electric motor is not achieved.

## BRIEF SUMMARY OF THE INVENTION

### 1. Objectives

An objective of the invention is to provide a wet electric motor driven pump which utilizes only a portion of the total fluid flow into the electric motor driven pump for cooling the electric motor components of the pump, preferably no more than a portion of the fluid flow into the electric motor driven pump which is required to meet its auxiliary fluid flow specification. Another objective of the invention is to provide increased high pressure pumping efficiency by directing most of the input fluid flow directly through the main pump and not through the electric motor components for cooling. Another objective of the invention is to provide for more uniform cooling of the electric motor components of the electric motor driven pump. Another objective of the invention is to provide for an electric motor driven pump in which the volume of high pressure fluid output can be varied over a large range while maintaining optimal cooling and efficiency of the electric motor. A final objective of the invention is to provide an electric

motor driven pump in which the electric motor operates at a higher efficiency at low operating temperatures.

2. Features

A wet electric motor driven pump comprises a main pump, pumping a specified working fluid, which is driven by a wet electric motor, operating submerged in the specified working fluid, and a means for bleeding, prior to entry into the main pump, a portion of the specified working fluid from the total flow of specified working fluid entering the wet electric motor driven pump to form an auxiliary fluid flow, which auxiliary fluid flow is substantially all of the fluid in which the wet electric motor operates and substantially all of the fluid which cools the wet electric motor.

As generally illustrated in Fig. 1, Fig. 2 and Fig. 3, a wet electric motor driven pump comprises a wet electric motor which is connected to drive a main pump which pumps a specified working fluid, preferably through a drive shaft in an in-line configuration. Preferably the wet electric motor is an AC induction motor and the main pump is an axial piston pump. The wet electric motor, drive shaft, main pump and other necessary components of the wet electric motor driven pump are preferably integrated and mounted in a common housing. Within the common housing there is a first cavity which houses the wet electric motor and a second cavity which houses the main pump.

The first cavity and second cavity are connected by at least one passage through which an auxiliary fluid flow may pass. Preferably, there is a hydrodynamic pump associated with the main pump to prevent cavitation of the main pump, and there is at least one additional hydrostatic pump which is associated with the first cavity and the second cavity and to pump the auxiliary fluid flow through the first cavity and second cavity to cool the wet electric motor and lubricate the main pump, wet electric motor and additional hydrostatic pump.

A total volume of the specified working fluid flows into the housing through a housing inlet and then flows through a passage to a main pump inlet. Prior to the main pump inlet, there is a bypass passage which allows a portion of the total volume of the specified working fluid to flow into the first cavity and second cavity to form an auxiliary flow which is of sufficient quantity to lubricate and cool the wet electric motor and meet an auxiliary fluid flow specification of the wet electric motor driven pump. The portion of the hydraulic fluid which is not bypassed as the auxiliary fluid flow goes into the main pump inlet and is substantially expelled through a main pump outlet, through a high pressure exit passage and out a high pressure housing outlet. Preferably, in the high pressure exit passage there may be a flow-through attenuator.

Preferably, at least one hydrostatic pump may be associated with the first cavity or second cavity, or both, to induce a uniform flow of fluid through the first and second cavities and expulsion of the auxiliary fluid flow through an auxiliary flow outlet at the wet electric motor driven pump auxiliary flow pressure and flow specification. Fluid seepage from the main pump is collected in the first cavity and joins the auxiliary fluid flow. The hydrostatic pump and additional hydrodynamic pump may be associated with the first cavity and second cavity in different configurations and, therefor, may pressurize the first cavity and second cavity in different configurations. Three preferred pressure configurations are: both first cavity and second cavity at auxiliary flow pressure; first cavity at main pump inlet pressure and second cavity at auxiliary flow pressure; or both first cavity and second cavity at main inlet pressure.

THE DRAWING

Fig. 1 is a longitudinal sectional view of a wet motor driven pump illustrating the invention in the first cavity and second cavity at auxiliary flow pressure configuration.

Fig. 2 is a longitudinal sectional view of a wet motor driven pump illustrating the invention in the first cavity at main pump inlet pressure and second cavity at auxiliary flow pressure configuration.

Fig. 3 is a longitudinal sectional view of a wet motor driven pump illustrating the invention in the first cavity and second cavity at main pump inlet pressure configuration.

DETAILED DESCRIPTION OF THE INVENTION

Description of the Illustrated Embodiments

Three embodiments of the invention, adapted to an aircraft high pressure hydraulic pump application, are illustrated in Fig. 1, Fig 2 and Fig. 3. Fig. 1 illustrates an embodiment of the invention in which both first cavity 15, which houses variable high pressure hydraulic pump 11, and second cavity 16, which houses electric motor 12, are at auxiliary flow pressure. Fig. 2 illustrates an embodiment of the invention in which first cavity 45, which houses variable high pressure hydraulic pump 41, is at variable high pressure hydraulic pump inlet pressure and second cavity 46, which houses electric motor 42, is at auxiliary flow pressure. Fig. 3 illustrates an embodiment of the invention in which both first cavity 75, which houses variable high pressure hydraulic pump 71, and second cavity 76, which houses electric motor 72, are at variable high pressure hydraulic pump inlet pressure. The different embodiments of the invention illustrated in Fig. 1, Fig. 2 and Fig. 3 are accomplished by the relative placement of the various internal pumping means which are associated with first and second cavities.

Fig. 1 Embodiment

Referring to Fig. 1, a wet electric motor driven hydraulic pump 10 comprises a variable high pressure hydraulic pump 11 which is connected to and driven by an electric motor 12 through drive shaft 13. Preferably, variable high pressure hydraulic pump 11 is a hydraulic axial piston pump and electric motor 12 is a wet AC induction motor. Variable high pressure hydraulic pump 11, Electric motor 12, and drive shaft 13 are mounted in common housing 14. Within common housing 14 there is a first cavity 15 which houses variable high pressure hydraulic pump 11 and a second cavity 16 which houses electric motor 12. First cavity 15 and second cavity 16 communicate with each other by passages 17 through which hydraulic fluid may circulate and communicate by passage 18 through which drive shaft 13 extends and is supported in passage 18 by ball bearing 19. Variable high pressure hydraulic pump 11 is supported in cavity 15 by roller bearing 20. Electric motor 12 comprises stator 21 which is attached to the inside of second cavity 16, and rotor 22 which is attached to drive shaft 13. Rotor 22 is supported within stator 21 and within second cavity 16 by ball bearing 19 and ball bearing 23 which support drive shaft 13.

The clearance between rotor 22 and stator 21 forms a cylindrical passage 24 around rotor 22 through which hydraulic fluid may flow. Additionally, located around the outside of stator 21 are a plurality of axial passages 25 through which hydraulic fluid may also flow. Preferably, the clearance between rotor 22 and stator 21 which forms cylindrical passage 24 is sized to maximize the operating parameters of electric motor 12, and then the size, number and radial placement of axial passages 25 are determined relative to the size of cylindrical passage 24 such that the hydraulic fluid flow through cylindrical passage 24 and axial passages 25 provides uniform cooling of electric motor 12 and meets the

auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 10.

The total working volume of hydraulic fluid which is utilized by electric motor driven hydraulic pump 10 enters electric motor driven hydraulic pump 10 through housing inlet 26 at reservoir pressure. The majority of the working volume of hydraulic fluid then flows through inlet passage 27 to hydrodynamic pump 28 and is then pumped by hydrodynamic pump 28 through inducer passage 29 into variable high pressure hydraulic pump inlet 30 by hydrodynamic pump 28 at a variable high pressure hydraulic pump inlet pressure sufficient to prevent cavitation of variable high pressure hydraulic pump 11. Preferably, hydrodynamic pump 28 is an inlet inducer-impeller, as taught by United States Patent No. 4,281,971 issued August 4, 1981 to Kouns. After passing through variable high pressure hydraulic pump 11, the hydraulic fluid is expelled from electric motor driven hydraulic pump 10 through variable high pressure hydraulic pump outlet 31, through a high pressure exit passage 32 and out a high pressure housing outlet 33. Preferably, after exiting variable high pressure hydraulic pump outlet 31 the hydraulic fluid may flow through a flow-through attenuator, which is not shown, that substantially reduces the pumping ripple effect of variable high pressure hydraulic pump 11.

An auxiliary flow of hydraulic fluid consisting of a portion of the working hydraulic fluid flow is bled from the working hydraulic fluid flow through bypass passage 34. The auxiliary flow may be bled off either prior to its entry into hydrodynamic pump 28, as illustrated, or after its exit from hydrodynamic pump 28. The auxiliary flow then passes through hydrostatic pump 35 and is pressurized to the auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 10. Preferably hydrostatic pump 35 is a gerotor which is driven by electric motor 12 through drive shaft 13.

After exiting hydrostatic pump 35, the auxiliary flow passes through and lubricates bearing 23 into the portion of second cavity 16 located to the right of electric motor 12. The auxiliary flow then passes through cylindrical passage 24 and axial passages 25 into the portion of second cavity 16 located to the left of electric motor 12. As the auxiliary flow passes through cylindrical passage 24 and axial passages 25, the electric motor 12 is cooled.

After flowing into the portion of second cavity 16 located to the left of electric motor 12, the auxiliary flow mixes with hydraulic fluid seepage from variable high pressure hydraulic pump 11. Hydraulic fluid seepage from variable high pressure hydraulic pump 11 circulates through first cavity 15, where it lubricates roller bearing 20 and variable high pressure hydraulic pump 11, and through passages 17 and passage 18, where it lubricates ball bearing 19, and into the portion of second cavity 16 located to the left of electric motor 12. The auxiliary flow is then discharged from electric motor driven hydraulic pump 10 through auxiliary flow outlet 36 at the auxiliary flow and pressure specifications of electric motor driven hydraulic pump 10.

Fig. 2 Embodiment

Referring to Fig. 2, a wet electric motor driven hydraulic pump 40 comprises a variable high pressure hydraulic pump 41 which is connected to and driven by an electric motor 42 through drive shaft 43. Preferably, variable high pressure hydraulic pump 41 is an axial piston pump and electric motor 42 is a wet AC induction motor. Variable high pressure hydraulic pump 41, electric motor 42, and drive shaft 43 are mounted in common housing 44. Within common housing 44 there is a first cavity 45 which houses variable high pressure hydraulic pump 41 and a second cavity 46 which houses electric motor 42. Variable high pressure hydraulic pump

41 is supported in first cavity 45 by roller bearing 47. First cavity 45 and second cavity 46 communicate with each other through hydrostatic pump 48 through which hydraulic fluid is pumped. Drive shaft 43 is supported in second cavity 46 by roller bearing 49.

Electric motor 42 comprises stator 50 which is attached to the inside of second cavity 46, and rotor 51 which is attached to drive shaft 43. Rotor 51 is supported within stator 50 and within second cavity 46 by ball bearing 52 and roller bearing 49. Roller bearing 49 also supports drive shaft 43 and hydrostatic pump 48. Hydrostatic pump 48 is located within first cavity 45 and attached to housing 44 with screws 53. The portion of second cavity 46 located to the right of electric motor 42 communicates with the exit port of hydrostatic pump 48 through roller bearing 49 and passages 54.

The clearance between rotor 51 and stator 50 forms a cylindrical passage 55 around rotor 51 through which hydraulic fluid may flow. Additionally, located around the outside of stator 50 are a plurality of axial passages 56 through which hydraulic fluid may also flow. Preferably, the clearance between rotor 51 and stator 50 which forms cylindrical passage 55 is sized to maximize the operating parameters of electric motor 42, and then the size, number and radial placement of axial passages 56 are determined relative to the size of cylindrical passage 55 such that the hydraulic fluid flow through cylindrical passage 55 and axial passages 56 provides uniform cooling of electric motor 42 and meets the auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 40.

The total working volume of hydraulic fluid which is utilized by electric motor driven hydraulic pump 40 enters electric motor driven hydraulic pump 40 through housing inlet 57 at reservoir pressure. The hydraulic fluid then flows through inlet passage 58 to hydrodynamic pump 59 and is then pumped by hydrodynamic pump 59

through inducer passage 60 into variable high pressure hydraulic pump inlet 61 by hydrodynamic pump 59 at a variable high pressure hydraulic pump inlet pressure sufficient to prevent cavitation of variable high pressure hydraulic pump 41. Preferably, hydrodynamic pump 59 is an inlet inducer-impeller, as taught by United States Patent No. 4,591,971 issued August 4, 1981 to Kouns. After passing through variable high pressure hydraulic pump 41, the hydraulic fluid is expelled from electric motor driven hydraulic pump 40 through variable high pressure hydraulic pump outlet 62, through a high pressure exit passage 63 and out a high pressure housing outlet 64. Preferably, after exiting variable high pressure hydraulic pump outlet 62 the hydraulic fluid may flow through a flow-through attenuator 65 which substantially reduces the pumping ripple effect of variable high pressure hydraulic pump 41.

An auxiliary flow of hydraulic fluid consisting of portion of the working hydraulic fluid flow sufficient to meet the auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 40 is bled from inducer passage 60 through bypass passage 66 into first cavity 45 at variable high pressure hydraulic pump inlet pressure. This auxiliary flow then passes through first cavity 45, where it combines with hydraulic fluid seepage from variable high pressure hydraulic pump 41 and lubricates variable high pressure hydraulic pump 41 and roller bearing 47, and into hydrostatic pump 48. Preferably hydrostatic pump 48 is a gerotor which is driven by electric motor 42 through drive shaft 43. The auxiliary flow is then expelled from hydrostatic pump 48, pressurized to the auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 40, through passages 54 and roller bearing 49 into the portion of second cavity 46 located to the right of electric motor 42. As the auxiliary flow passes through roller bearing 49, roller bearing 49 is lubricated. The

auxiliary flow then passes through cylindrical passage 55 and axial passages 56 into the portion of second cavity 46 located to the left of electric motor 42. As the auxiliary flow passes through second cavity 46, the electric motor 42 is cooled and roller bearing 49 and ball bearing 52 are lubricated.

The auxiliary flow then passes from second cavity 46 through auxiliary flow discharge passage 67 and is then discharged from electric motor driven hydraulic pump 40 through auxiliary flow outlet 68 at the auxiliary flow and pressure specifications of electric motor driven hydraulic pump 40.

Fig. 3 Embodiment

Referring to Fig. 3, a wet electric motor driven hydraulic pump 70 comprises a variable high pressure hydraulic pump 71 which is connected to and driven by an electric motor 72 through drive shaft 73. Preferably, variable high pressure hydraulic pump 71 is a hydraulic axial piston pump and electric motor 72 is a wet AC induction motor. Variable high pressure hydraulic pump 71, Electric motor 72, and drive shaft 73 are mounted in common housing 74. Within common housing 74 there is a first cavity 75 which houses variable high pressure hydraulic pump 71 and a second cavity 76 which houses electric motor 72. First cavity 75 and second cavity 76 communicate with each other through passage 77, through which drive shaft 73 extends, and through second hydrodynamic pump 78. Second hydrodynamic pump 78 also receives hydraulic fluid from first cavity 75 through hydrodynamic pump inlet 79 and discharges hydraulic fluid into second cavity 76 through hydrodynamic pump outlet 80. Drive shaft 73 is supported in passage 77 by ball bearing 81 that is lubricated by the hydraulic fluid which may flow through passage 77. Variable high pressure hydraulic pump 71 is supported in cavity 75 by roller bearing 82.

Electric motor 72 comprises stator 83 which is attached to the inside of second cavity 76, and rotor 84 which is attached to drive shaft 73. Rotor 84 is supported within stator 83 and within second cavity 76 by ball bearing 81 and roller bearing 85 which support drive shaft 73. Hydrostatic pump 86 is located within second cavity 76 and attached to housing 74.

The clearance between rotor 84 and stator 83 forms a cylindrical passage 87 around rotor 84 through which hydraulic fluid may flow. Additionally, located around the outside of stator 83 are a plurality of axial passages 88 through which hydraulic fluid may also flow. Preferably, the clearance between rotor 84 and stator 83 which forms cylindrical passage 87 is sized to maximize the operating parameters of electric motor 72, and then the size, number and radial placement of axial passages 88 are determined relative to the size of cylindrical passage 87 such that the hydraulic fluid flow through cylindrical passage 87 and axial passages 88 provides uniform cooling of electric motor 72 and meets the auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 70.

The total working volume of hydraulic fluid which is utilized by electric motor driven hydraulic pump 70 enters electric motor driven hydraulic pump 70 through housing inlet 89 at reservoir pressure. The hydraulic fluid then flows through inlet passage 90 to first hydrodynamic pump 91 and is then pumped by first hydrodynamic pump 91 through inducer passage 92 into variable high pressure hydraulic pump inlet 93 by first hydrodynamic pump 91 at a variable high pressure hydraulic pump inlet pressure sufficient to prevent cavitation of variable high pressure hydraulic pump 71. Preferably, first hydrodynamic pump 91 is an inlet inducer-impeller, as taught by United States Patent No. 4,281,971 issued August 4, 1981 to Kouns. After passing through variable high pressure hydraulic pump 71, the

hydraulic fluid is expelled from electric motor driven hydraulic pump 70 through variable high pressure hydraulic pump outlet 94, through a high pressure exit passage 95 and out a high pressure housing outlet 96. Preferably, after exiting variable high pressure hydraulic pump outlet 94 the hydraulic fluid may flow through a flow-through attenuator 97 which substantially reduces the pumping ripple effect of variable high pressure hydraulic pump 71.

A auxiliary flow of hydraulic fluid consisting of portion of the working hydraulic fluid flow sufficient to meet the auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 70 is bled from inducer passage 92 through bypass passage 98 into first cavity 75 at variable high pressure hydraulic pump inlet pressure. This auxiliary flow then passes through first cavity 75, where it combines with hydraulic fluid seepage from variable high pressure hydraulic pump 71 and lubricates variable high pressure hydraulic pump 71 and roller bearing 82 and then flows through both passage 77, lubricating ball bearing 81, and passage 79 into second hydrodynamic pump 78, where it is pumped, through hydrodynamic pump outlet 80, into the portion of second cavity 76 located to the right of electric motor 72. The auxiliary flow then passes through cylindrical passage 87 and axial passages 88 into the portion of second cavity 76 located to the left of electric motor 72. As the auxiliary flow passes through second cavity 76, electric motor 72 is cooled.

The auxiliary flow then passes from the portion of second cavity 76 located to the left of electric motor 72 through hydrostatic pump inlets 99 into hydrostatic pump 86. Preferably hydrostatic pump 86 is a gerotor which is driven by electric motor 72 through drive shaft 73. The auxiliary flow is then expelled, pressurized to the auxiliary flow pressure and flow specifications of electric motor driven hydraulic pump 70, from hydrostatic

pump 86 through hydrostatic pump outlet 100 into auxiliary flow discharge passage 101. The auxiliary flow is then discharged from electric motor driven hydraulic pump 70 through auxiliary flow outlet 102.

Whereas the invention is here illustrated and described with specific reference to several embodiments thereof presently contemplated as the best mode in carrying out such invention, it is to be understood that various changes may be made in adapting the invention to additional embodiments without departing from the broad inventive concepts disclosed herein and comprehended by the claims that follow.

CLAIMS

1. A wet electric motor driven pump comprising:

(a) a main pump which pumps a specified working fluid;

(b) a wet electric motor which is connected to drive the main pump; and

(c) a means for bleeding, prior to entry into the main pump, a portion of the specified working fluid from the total flow of specified working fluid entering the wet electric motor driven pump to form an auxiliary fluid flow, which auxiliary fluid flow is substantially all of the fluid in which the wet electric motor operates and substantially all of the fluid which cools the wet electric motor.

2. A wet electric motor driven pump as recited in Claim 1 further comprising a means for circulating the auxiliary fluid flow through the wet electric motor to provide uniform cooling of the wet electric motor.

3. A wet electric motor driven pump as recited in Claim 2 wherein the means for circulating further comprises at least one passage through the electric motor through which the auxiliary fluid flow passes.

4. A wet electric motor driven pump as recited in claim 3 wherein the means for circulating further comprises at least one additional pump which pumps the auxiliary fluid flow through the electric motor.

5. A wet electric motor driven pump as recited in Claim 4 further comprising a common housing which houses the main pump, the wet electric motor, the means for bleeding and the means for circulating.

6. A wet electric motor driven pump as recited in Claim 5 wherein the specified working fluid is hydraulic fluid.

7. A wet electric motor driven pump comprising:

(a) a main pump which pumps a specified working fluid and is housed within a pump cavity located in a pump housing;

(b) a wet electric motor which is housed within a motor cavity located in a motor housing and is connected to drive the main pump; and

(c) a means for bleeding, prior to entry into the main pump, a portion of the specified working fluid from the total flow of specified working fluid entering the wet electric motor driven pump to form an auxiliary fluid flow, which auxiliary fluid flow is substantially all of the fluid in which the wet electric motor operates and substantially all of the fluid which cools the wet electric motor.

8. A wet electric motor driven pump as recited in Claim 7 further comprising a means for circulating the auxiliary fluid flow through the motor cavity to provide uniform cooling of the wet electric motor and in the motor cavity and pump cavity to provide lubrication of the main pump and wet electric motor.

9. A wet electric motor driven pump as recited in Claim 8 wherein the means for circulating further comprises at least one passage through the electric motor through which the auxiliary fluid flow passes.

10. A wet electric motor driven pump as recited in Claim 9 wherein the means for circulating further comprises at least one additional pump which circulates the auxiliary fluid flow through the passage, the motor cavity and the pump cavity.

11. A wet electric motor driven pump as recited in Claim 10 wherein placement of the additional pump before or after the motor cavity and the pump cavity provides substantially the same fluid pressure in the motor cavity and the pump cavity.

12. A wet electric motor driven pump as recited in Claim 11 wherein the motor housing and pump housing are integral.

13. A wet electric motor driven pump as recited in Claim 12 wherein the specified working fluid is hydraulic fluid.

14. A wet electric motor driven pump as recited in Claim 10 wherein placement of the additional pump between the motor cavity and the pump cavity provides for different fluid pressures in the motor cavity and the pump cavity.

15. A wet electric motor driven pump as recited in Claim 14 wherein the motor housing and pump housing are integral.

16. A wet electric motor driven pump as recited in Claim 15 wherein the specified working fluid is hydraulic fluid.

17. A wet electric motor driven pump having a working output flow and pressure and an auxiliary output flow and pressure comprising:

(a) a main pump which pumps a specified working fluid and is housed within a pump cavity located in a pump housing;

(b) a wet electric motor housed within a motor cavity located in a motor housing and is connected to drive the main pump; and

(c) a means for bleeding, prior to entry into the main pump, a portion of the specified working fluid from the total flow of specified working fluid entering the wet electric motor driven pump to form an auxiliary fluid flow, which auxiliary fluid flow is substantially all of the fluid in which the wet electric motor operates and substantially all of the fluid which cools the wet electric motor.

18. A wet electric motor driven pump as recited in Claim 17 further comprising a means for circulating the auxiliary fluid flow through the motor cavity to provide uniform cooling of the wet electric motor and in the motor cavity and pump cavity to provide lubrication of the main pump and wet electric motor.

19. A wet electric motor driven pump as recited in Claim 18 wherein the means for circulating further comprises at least one passage for the auxiliary fluid flow to pass through the electric motor, which passage is sized to provide uniform cooling of the wet electric motor.

20. A wet electric motor driven pump as recited in Claim 19 wherein the means for circulating further comprises a hydrostatic pump which is located before the motor cavity and the pump cavity and circulates the auxiliary fluid flow through the motor cavity, the pump cavity and the passage at the auxiliary fluid output flow and pressure.

21. A wet electric motor driven pump as recited in Claim 20 wherein the motor housing and pump housing are integral.

22. A wet electric motor driven pump as recited in Claim 23 wherein the specified working fluid is hydraulic fluid.

23. A wet electric motor driven pump as recited in Claim 19 wherein the means for circulating further comprises at least one hydrodynamic pump located before the motor cavity and the pump cavity which pumps the auxiliary fluid flow at sufficient pressure to prevent cavitation of a hydrostatic pump, located between the motor cavity and the pump cavity, which circulates the auxiliary fluid flow through the motor cavity and the passage at the auxiliary fluid output flow and pressure.

24. A wet electric motor driven pump as recited in Claim 23 wherein the motor housing and pump housing are integral.

25. A wet electric motor driven pump as recited in Claim 24 wherein the specified working fluid is hydraulic fluid.

26. A wet electric motor driven pump as recited in Claim 19 wherein the means for circulating further comprises at least one hydrodynamic pump associated with the motor cavity, the pump cavity and the passage which pumps the auxiliary fluid flow at sufficient pressure to prevent cavitation of a hydrostatic pump, located after the motor cavity and the pump cavity, which pumps the auxiliary fluid flow at the auxiliary fluid output flow and pressure.

27. A wet electric motor driven pump as recited in Claim 26 wherein the motor housing and pump housing are integral.

28. A wet electric motor driven pump as recited in Claim 27 wherein the specified working fluid is hydraulic fluid.

29. A wet electric motor pump which pumps hydraulic fluid at a working output flow and pressure and an auxiliary fluid output flow and pressure comprising:

(a) a main pump supported by a pump support means within a pump cavity located in a pump housing;

(b) an electric motor which is supported by a motor support means within a motor cavity located in a motor housing and is connected to drive the main pump;

(c) a first hydrodynamic pump associated with and driven by the main pump which provides sufficient hydraulic fluid flow to the main pump to prevent cavitation of the main pump;

(d) a means for bleeding into the pump cavity, after the first hydrodynamic pump but prior to entry into the main pump, a portion of the hydraulic fluid flow from the total hydraulic fluid flow entering the electric motor pump to form an auxiliary fluid flow, which auxiliary fluid flow is substantially all of the fluid which lubricates the main pump, pump support means, motor support means and is substantially all of the fluid in which the electric motor operates and which cools and lubricates the electric motor;

(e) a second hydrodynamic pump located between the pump cavity and the motor cavity which is driven by the electric motor and pumps the auxiliary fluid flow from the pump cavity into and through the motor cavity at a flow rate sufficient to prevent cavitation of a hydrostatic pump, located at an exit of the motor cavity, which pumps the auxiliary fluid flow out of the motor cavity at the auxiliary fluid output flow and pressure; and

(f) at least one passage through the electric motor through which the auxiliary fluid flows and which provides for uniform cooling of the electric motor.

30. A wet electric motor pump as recited in Claim 29 wherein the electric motor is an AC induction motor; the main pump is a hydraulic axial piston pump; the main pump is connected to and driven by the electric motor through a drive shaft; the pump support means and motor support means are bearings; the means for bleeding is a bypass passage; and the passage through the electric motor is formed by a cylindrical passage formed from a clearance gap between a rotor and a stator of the electric motor, sized to maximize the operating parameters of the electric motor, and by at least one axial passage through the stator, the size, number and placement of the axial passage being determined relative to the size of the cylindrical passage such that the auxiliary fluid flow through the cylindrical passage and the axial passage provide uniform cooling of the electric motor.

31. A wet electric motor pump as recited in Claim 30 wherein the motor housing and pump housing are integral.

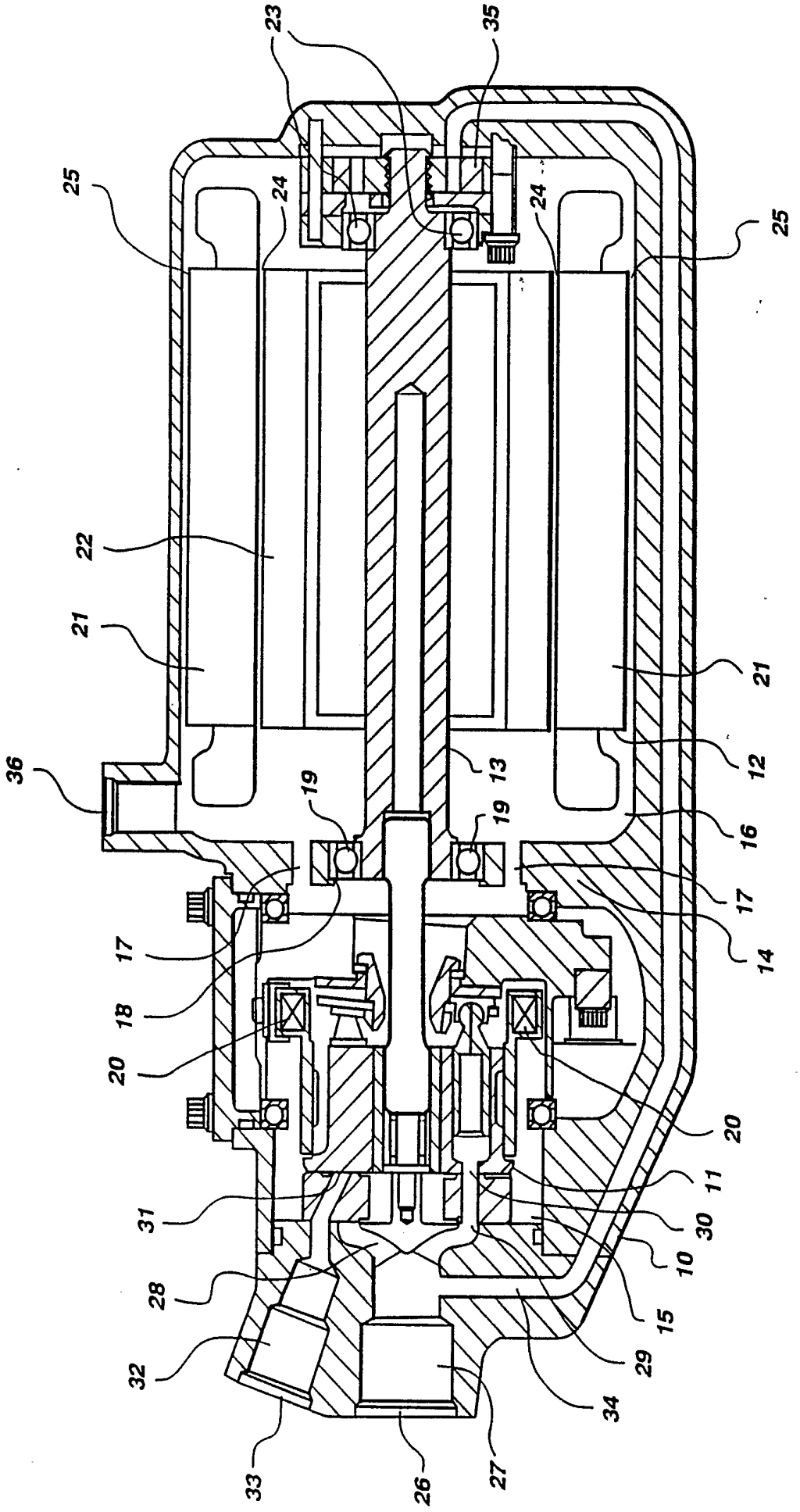

23
35
25
24
24
25
22
21
21
36
19
19
13
12
16
17
17
14
18
20
20
11
31
30
10
28
15
29
32
34
33
26
27

Fig. 1

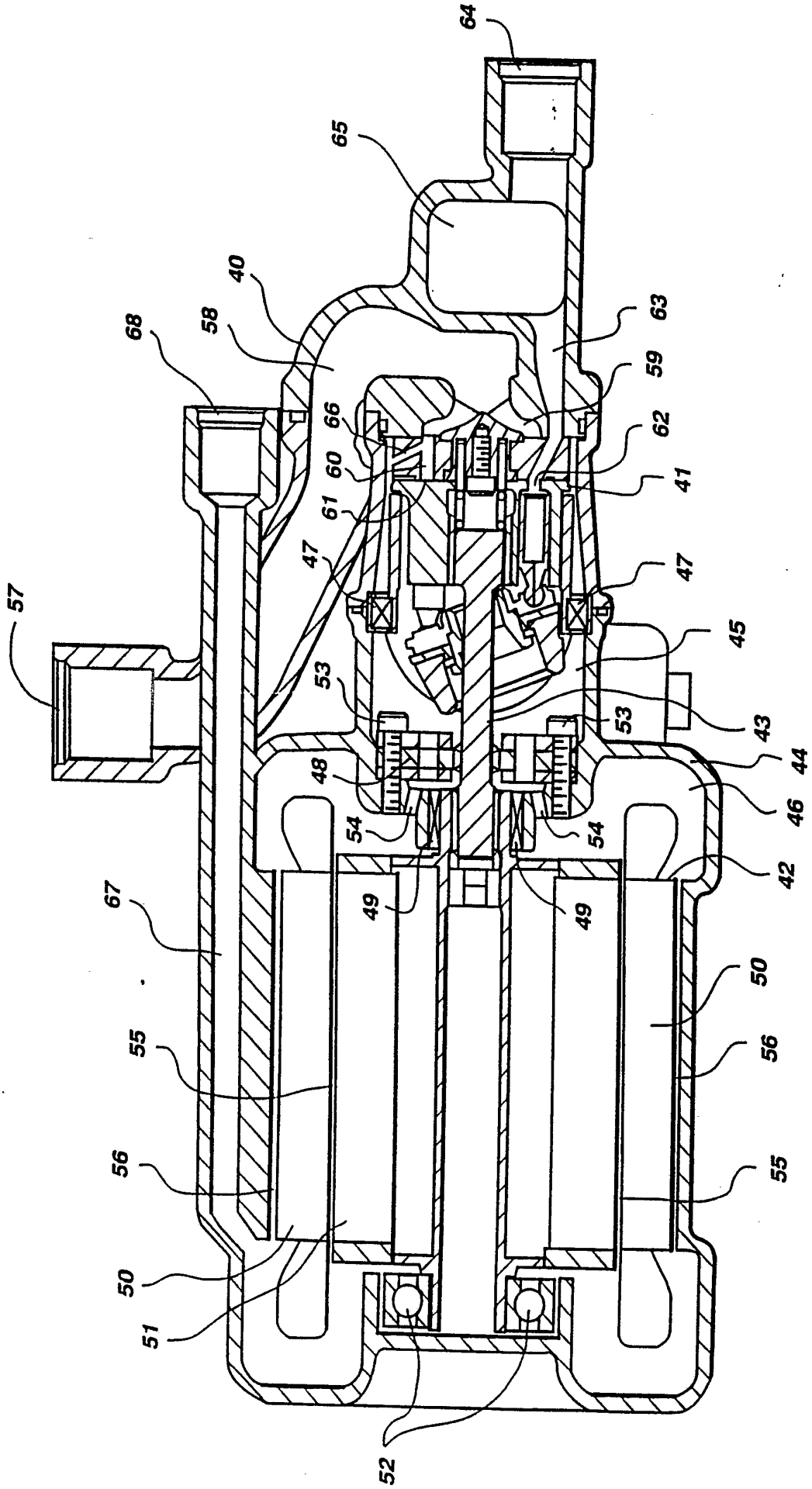

64
65
40
58
68
63
59
62
66
60
41
61
47
47
57
45
53
53
43
48
44
46
54
54
42
67
49
49
50
55
56
56
55
50
51
52

Fig. 2

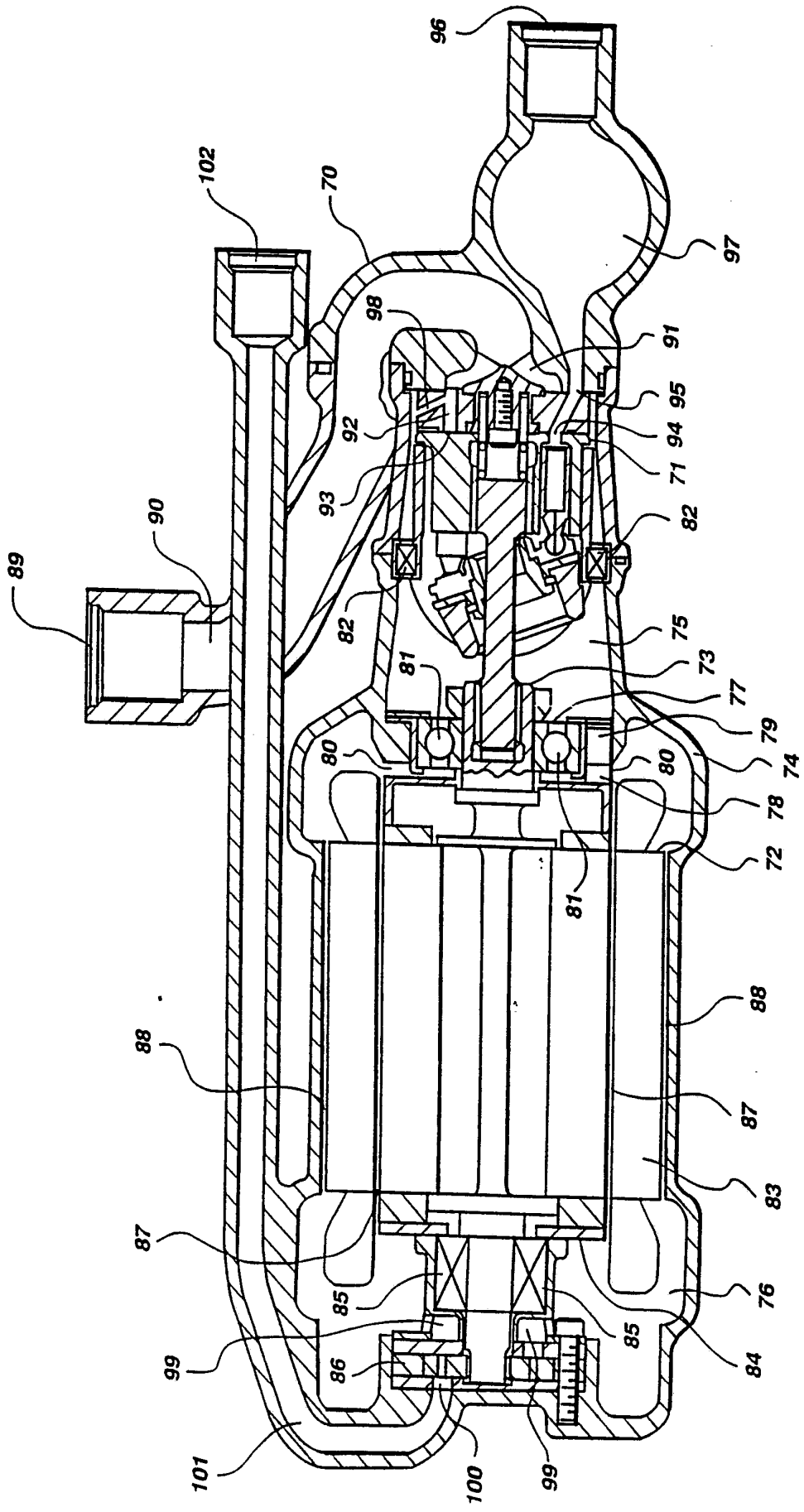

96
102
70
97
98
91
95
92
94
71
93
82
90
89
82
75
73
81
77
79
80
80
74
78
72
81
88
88
87
87
83
85
76
85
84
99
86
101
100
99

Fig. 3

# INTERNATIONAL SEARCH REPORT

PCT/US93/02340

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(5) :F04B 39/02; F04D 1/06
US CL :417/203, 368, 369
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 417/203, 368, 369

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | Abex Aerospace; "Light Weight AC Motor Pump"; issued January 1991, pages 1-6, especially page 3. | 1-10, 14-19, and 22-25 |
| X | Pneumo Abex Corporation, "AC Motor Pump for the Boeing 777 Aircraft", Abex/BAC Technical Coordination Meeting, issued 09 November 1990, pages 1-13, especially page 11. | 1-21 |
| X | US, A, 4,470,772 (Gannaway) 11 September 1984, see entire document | 1-10, 14-19 |
| A | US, A, 4,865,522 (Radermacher) 12 September 1989, see entire document | 1-31 |
| A | DE, A, 2,331,917 (Harle) 23 January 1975, see entire document | 1-31 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 April 1993

Date of mailing of the international search report

16 JUN 1993

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. NOT APPLICABLE

Authorized officer

RICHARD E. GLUCK

NGUYEN NGOC-HO
INTERNATIONAL DIVISION

Telephone No. (703) 308-1936

Form PCT/ISA/210 (second sheet)(July 1992)★