(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 January 2016 (21.01.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/010892 A1

(51) International Patent Classification:
F04B 17/03 (2006.01) *F04B 9/02* (2006.01)

(21) International Application Number:
PCT/US2015/040134

(22) International Filing Date:
13 July 2015 (13.07.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/024,283 14 July 2014 (14.07.2014) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: MODULAR HYDRAULIC POWER PACK

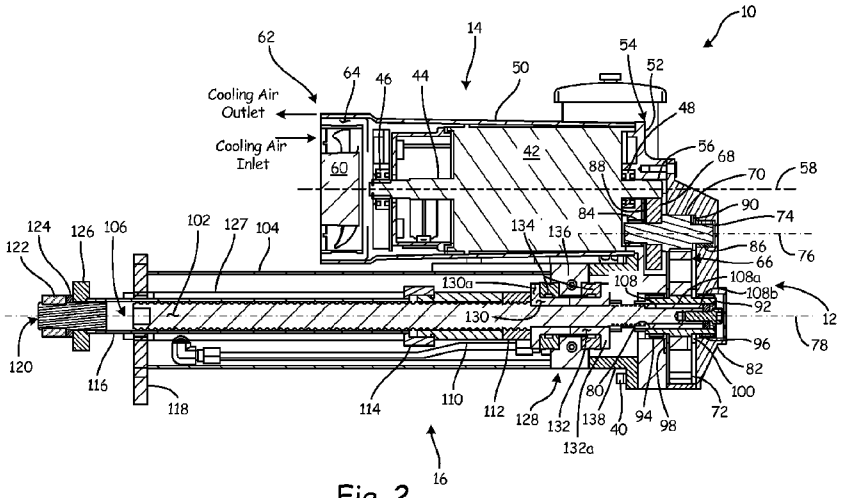

Fig. 2

(57) **Abstract**: A gear train assembly for use in a modular hydraulic power pack includes a gear train, a housing, and a plurality of supports disposed between the gear train and the housing to radially and axially restrain the gear train relative to the housing. The gear train couples a drive assembly to a pump assembly. The drive assembly is coupled to an input gear of the gear train, and the pump assembly is coupled to an output gear of the gear train. The output gear has a female spline that permits the pump assembly to be removable from the gear train assembly.

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MODULAR HYDRAULIC POWER PACK

BACKGROUND

The present invention relates generally to gear train assemblies, and more particularly, to gear train assemblies used to facilitate modular hydraulic power packs.

Hydraulic power packs generate pressurized working fluid to be utilized in hydraulic systems and/or hydraulically-powered equipment. Typically, hydraulic power packs include a pump to supply a working fluid at a specified pressure and flow rate and a motor to drive the pump. The pump and motor are selected to meet the specific operational requirements of the power pack (i.e., the desired flow rate and pressure of the working fluid). Supplementary components, such as pressure regulators, pressure relief valves, recirculation lines, and the like can be incorporated into the hydraulic power pack to facilitate satisfaction of the operational requirements.

As such, the components of each hydraulic power pack are tailored to a particular application of the power pack or are over-specified to operate at a maximum operating condition as well as less stringent operating conditions. Tailoring the power pack to a specific application requires the operator to have several power packs, different components among power packs increasing maintenance costs while oversizing the power pack increases the cost of operation when the power pack operates below the maximum operating condition. Additionally, the hydraulic power pack components, in particular, the pump and the motor, require regular maintenance to ensure operational performance of the power pack, which among other things, includes disassembly of the components, replacing worn components, reassembly of the components, and verifying the power pack performance through testing. The time and tooling required to perform maintenance tasks such as these also increase the cost of operating the hydraulic power pack.

Therefore, a need exists for a modular hydraulic power pack that can be readily customized to an application and maintained by replacing the modules of the power pack.

SUMMARY

In one embodiment, a gear train assembly for use in a modular hydraulic power pack includes a gear train, a housing, and a plurality of supports disposed between the gear train and the housing to radially and axially restrain the gear train relative to the housing. The gear train assembly is configured to couple a drive assembly to a pump

assembly. The drive assembly is coupled to an input gear of the gear train, and the pump assembly is coupled to an output gear of the gear train. The output gear has a female spline that permits the pump assembly to be removable from the gear train assembly.

In another embodiment, a modular hydraulic power pack includes a drive assembly, a pump assembly, and a gear train assembly coupling the drive assembly to the pump assembly. The drive assembly includes a motor enclosed within a housing and a first shaft with a drive pinion at an end of the first shaft. The pump assembly includes a screw, a pump housing enclosing the screw, and a thrust bearing restraining the screw relative to the pump housing in a direction substantially parallel to a rotational axis of the screw. The screw extends from a first end to a second end in which the first end has a male spline. The gear train assembly includes a gear train housing enclosing the gear train assembly, an input gear enmeshed with the drive pinion, an output gear having a female spline at an inner diameter of the output gear enmeshed with the male spline of the screw. The gear train assembly further includes a second stage pinion axially adjacent to the input gear and a gear shaft that extends along a common rotational axis of the input gear and the second stage pinion. The gear shaft rotatably couples the input gear to the second stage pinion that is enmeshed with the output gear. The pump assembly is removably attached to the gear train assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of a hydraulic power pack having modular driving, pump, and gear train assemblies.

FIG. 2 is a cross-sectional view of the hydraulic power pack taken along line 2-2 in FIG. 1.

DETAILED DESCRIPTION

FIG. 1 is an isometric view of hydraulic power pack 10, which includes, among other components discussed below, gear train assembly 12 that couples drive assembly 14 to pump assembly 16. Drive assembly 14 supplies mechanical power to pump assembly 16 through gear train assembly 12. Pump assembly 16 provides hydraulic power to manifold block 18 via a working fluid (not shown in FIG. 1) contained within pump assembly 16.

Manifold block 18 is equipped with at least one outlet 20 and at least one inlet 22 to supply and retrieve, respectively, the working fluid from the hydraulically-driven component or system attached to power pack 10. Multiple inlets 22 and outlets 20 can be attached to manifold block 18 for operating multiple hydraulically-driven

components. For example, manifold block 18 can have four inlets 22 and outlets 20 as shown in FIG. 1 for operating up to four hydraulically-driven components or systems. Each inlet 22 and outlet 20 is adapted to be mechanically attached to pipe and/or hose (not shown in FIG. 1) to facilitate circulation of the working fluid to the hydraulically-driven component or system. Preferably, each inlet 22 and outlet 20 is a quick-disconnect hydraulic connection known in the art.

Reservoir 24 contains a volume of make-up working fluid to replenish fluid that has leaked out or is otherwise lost from power pack 10 or components connected to power pack 10. Reservoir 24 includes bin 26, cap 28, and fluid indicator 30. Bin 26 has a generally cylindrical body equipped with a generally hemispherical end oriented towards manifold block 18. A threaded end of bin 26 opposite the hemispherical end engages mating threads of cap 28. When attached, bin 26 and cap 28 form a reservoir that is fluidly connected to manifold block 18 at pipe connection 32. As the working fluid within reservoir 24 depletes, fluid indicator 30 permits an operator to determine the volume of working fluid within reservoir 24.

Pressure gage 34 and pressure relief valve 36 are fluidly connected to manifold block 18. Gage 34 is configured to determine the pressure of the working fluid within manifold block 18, and pressure relief valve 36 discharges working fluid from manifold block 18 when a pressure of the working fluid within manifold block 18 exceeds a pressure set point. Gage 34 and valve 36 each are any gage or valve known in the art suitable to perform these functions.

Gear train assembly 12 and drive assembly 14 form a first module, and pump assembly 16 forms a second module. The first and second modules are a self-contained such that pump assembly 16 can be readily disassembled for maintenance, module replacement, and customization of output pressure and flow of a working fluid contained within power pack 10. In some embodiments, gear train assembly 12 is coupled to drive assembly 14 with a plurality of fasteners 38 and is coupled to pump assembly 16 with a plurality of fasteners 40 (see FIG. 2), although any other suitable means of mechanical attachment could be used. When fasteners 38 and 40 are used, assemblies 12, 14, and 16 can be disassembled and assembled using hand tools (e.g., a wrench), thereby eliminating a need for specialized tools and expertise.

FIG. 2 is a cross-sectional view of hydraulic power pack 10 taken along line 2-2 in FIG. 1 showing gear train assembly 12 coupling drive assembly 14 to pump assembly 16. As will be described in further detail below, gear assembly 12 and drive

assembly 14 form a self-contained module that can be separated from pump assembly 16 by removing fasteners 40 that extend through pump assembly 16 into gear train assembly 12. Fasteners 40 can be manufactured from any suitable materials known in the art and can be configured in any suitable bolt pattern necessary to support pump assembly 16 from gear train assembly 12. Although only one fastener 40 is shown in FIG. 2, it shall be understood that a symmetrical pattern of fasteners 40 are disposed about pump assembly 16 and extend through a portion thereof to affix pump assembly 16 to gear train assembly 12.

Drive assembly 14 provides mechanical power to power pack 10. In the embodiment shown in FIG. 2, drive assembly 14 includes brushless motor 42 as is known in the art. Motor 42 has shaft 44 that extends between bearings 46 and 48. Motor 42 is disposed within housing 50, which encloses motor 42. Specifically, bearing 46 is disposed between shaft 44 and housing 50 to radially restrain motor 42 with respect to housing 50. Similarly, bearing 48 is disposed between shaft 44 and end plate 52 to radially restrain motor 42 with respect to housing 50, end plate 52 engaging inboard side 54 of drive assembly 14. For interfacing with gear train assembly 12, motor 42 has drive pinion 56 disposed at inboard end 54 of shaft 44. Brushless motor 42 receives three-phase alternating current at a specified voltage to cause motor 42 to rotate about axis 58, which extends through a geometric center of motor 42. Rotation of motor 42 causes drive pinion 56 to provide mechanical power to gear train assembly 12.

Optionally, motor 42 can include fan 60 disposed at outboard end 62 of drive assembly 14 as depicted in FIG. 2. Fan 60 drives cooling air from the ambient environment into housing 50 where it provides cooling to motor 42. After cooling motor 42, the cooling air is exhausted from housing 50 at any suitable location. In some embodiments, the cooling air is exhaust through duct 64 surrounding fan 60 at outboard end 56 of drive assembly 14.

Although drive assembly 14 is described with reference to brushless motor 42, other types of motors can be used to drive gear train assembly 12. For example, motor 42 can be replaced with other types of electric motors (e.g., a permanent magnet motor) or an air-operated motor or other suitable motors that are known in the art.

Gear train assembly 12 includes gear train 66 to transmit mechanical power from drive assembly 14 to pump assembly 16. Gear train 66 includes input gear 68, secondary pinon gear 70, and output gear 72. Gear 68 is enmeshed with drive pinion 56 of drive assembly 14 to transfer mechanical power produced by drive assembly 14 to

gear train assembly 12. Secondary pinion gear 70 is adjacent to gear 68 along shaft 74, which extends through a common rotational axis 76 of gears 68 and 70. Gears 68 and 70 can be attached to shaft 74 or be integrally-formed with shaft 74. Preferably, secondary pinion gear 70 is integral to shaft 74 and gear 68 is attached to shaft 74 as is shown in FIG. 2. Output gear 72 is enmeshed with secondary pinion gear 70 and, therefore, rotates about axis 78 that is offset from axis 74. Output gear 72 includes female spline 80 located along an inner diameter of output gear 72. Female spline 80 is configured to permit bidirectional displacement of a mating component along axis 78. Preferably, female spline 80 is the female half of a parallel key spline formed by multiple grooves extending substantially parallel to axis 78 along the inner diameter of output gear 72.

Gears 52, 68, 70, and 72 each have gear teeth extending from an outer diameter surface. The pitch diameter and the number of teeth contained on each gear are used to determine an effective gear ratio of gear train 66. The specific gear ratio of gear train 66 is related to the rotational speed of motor 42 and the desired rotational speed of pump assembly 16. Generally, the gear ratio between two mating gears is determined by dividing the number of teeth of the driven gear by the number of teeth of the driving gear. When the driven gear has more teeth than the driving gear (i.e., a gear ratio greater than 1.0), the driven gear rotates slower than the driving gear. Such an arrangement is considered a reducing gear set. In some embodiments, the multiple reducing sets can be used. In the embodiment shown in FIG. 2, gear 68 has more teeth than driving pinion 52, and output gear 72 has more teeth than secondary pinion gear 70. Thus, gear train 66 is a two-stage, reducing gear set in some embodiments.

Gear train 66 is enclosed and supported by housing 82 and end plate 52. Using an arrangement of bearings and bushings, as will be discussed below, gear train 66 is supported within gear train assembly 12 such that assembly 12 along with drive assembly 14 is self-contained. Because gear train 66 is self-contained and female spline 80 permits axial displacement of pump assembly 16, pump assembly 16 is removeable from hydraulic power pack 10 without disturbing gear train assembly 12 and drive assembly 14.

Gears 68 and 70 along with shaft 74 are supported within gear train assembly 12 by bearings 84 and 86 arranged at opposing ends of shaft 74. Bearing 84 is positioned between shaft 74 and end plate 52 to radially restrain shaft 74 with respect to end plate 52, and bearing 86 is located between shaft 74 and housing 82 to radially restrain shaft 74 with respect to housing 82. Bushings 88 and 90 axially restrain gears 68

and 70 within gear train assembly 12. Specifically, bushing 88 is adjacent to bearing 84 and is disposed between gear 68 and end plate 52 to prevent gear 68 from moving towards bearing 82 along axis 76. Likewise, bushing 90 is adjacent to bearing 86 and is disposed between gear 70 and housing 82 to prevent gear 70 from translating towards bearing 86 along axis 76.

Output gear 72 is restrained within gear train assembly 12 in a manner similar to gears 68 and 70. Output gear 72 includes hub 92. Hub 92 extends axially relative to axis 78 from opposing faces of output gear 72. Output gear 72 is radially restrained within gear train assembly 12 by bearings 94 and 96 and axially restrained within gear train assembly 12 by bushings 98 and 100. Bearing 94 is disposed between hub 92 and end plate 52, and bearing 96 is disposed between hub 92 and housing 82. Bushing 98 is located between output gear 72 and end plate 52 to limit displacement of output gear 72 towards bearing 94, and bushing 100 is located between output gear 72 and housing 82 to limit displacement of output gear 72 towards bearing 96. Bearings 84, 86, 94, and 96 can be any suitable bearing known in the art, for example, needle bearings. Similarly, bushings 88, 90, 98, and 100 can be any suitable bushing known in the art.

Pump assembly 16 coverts mechanical power from gear train assembly 12 to hydraulic power for operating hydraulically-operated machines or systems. Pump assembly 16 includes screw 102 enclosed within pump housing 104. Screw 102 extends from output gear 72 of gear train assembly 12 along axis 78 to free end 106. In some embodiments, screw 102 has shaft extension 108 with male spline 108a. Shaft extension 108 has internal threads that engage an external thread at an end of screw 102. Additionally, shaft extension 108 includes pilot surface 108b. Pilot surface 108b has a diameter that forms a locating fit with the radially innermost portion of female spline 80. In other embodiments, shaft extension 108 is integral to screw 102. Male spline 108a is configured to engage female spline 80 of output gear 72. Preferably, male spline 108a is the male half of a parallel key spline formed by multiple protrusions extending from an outer surface of screw 102 to engage an equal number of corresponding grooves on spline 80. Thus, male spline 108a and female spline 80 permit bidirectional displacement of screw 102 along axis 78 while coupling output gear 72 to screw 102 in circumferential and radial directions relative to axis 78.

Traveling nut 110 has internal threads along an inner diameter thereof that engage external threads of screw 102. Preferably, traveling nut 110 has internal threads that cooperate with the external threads of screw 102 to form a portion of a closed-loop

track (not shown in FIG. 2). The closed-loop track is configured to house ball bearings (not shown in FIG. 2) that reduce frictional forces between screw 102 and nut 110. When this arrangement is utilized, screw 102 is a ball screw, and nut 110 is a ball nut as is known in the art.

When drive assembly 14 and gear train assembly 12 cause screw 102 to rotate about axis 78, traveling nut 110 translates axially along an outer surface of screw 102. Buffer 112 is a resilient material arranged concentrically with screw 102 to dampen vibrations from translating nut 110 and to prevent nut 110 from impacting thrust bearing assembly 128, which is discussed in detail below. Coupler 114 engages a circumferentially-extending groove within traveling nut 110 to transmit axial displacement of nut 110 to cylinder 116. In some embodiments, coupler 114 is integral to cylinder 116. Cylinder 116 is disposed concentrically with screw 102 such that free end 106 is guided along an inner surface of cylinder 116. As traveling nut 110 translates linearly along screw 102, cylinder 116 is guided through an aperture in housing end plate 118. Cylinder 116 has rod 120 inserted into a free end of cylinder 116 outside of pump housing 104. Nut 122 engages external threads of rod 120. Nut 122 and washer 124 attach plate 126 to an end of cylinder 116. Cylinder 116 extends perpendicularly to screw 102 and couples cylinder 116 to adjacent hydraulic cylinders 127 disposed on opposing sides of plate 126. Thus, rotatory motion generated by drive assembly 14 and transmitted by gear train assembly 12 is converted to linear motion within pump assembly 16 by screw 102 and travelling nut 110. This linear motion is converted to hydraulic power by actuating one or more hydraulic cylinders coupled to cylinder 116 by plate 126. Hydraulic cylinders 127 supply working fluid through outlets 20 and receive fluid through inlets 22 to operate the hydraulically-powered components or systems attached to power pack 10.

Screw 102 is restrained axially within pump housing 104 by thrust bearing assembly 128. Thrust bearing assembly 128 includes collars 130 and 132, which engage an unthreaded outer surface of screw 102 between steps formed within screw 102. Collars 130 and 132 have flanges 130a and 132a, respectively for axially restraining bearings 134 within thrust bearing assembly 128. Disposed between bearings 134 is thrust flange 136 which engages pump housing 104. Thus, thrust bearing assembly 128 transmits axial forces to pump housing 104 that result from translating traveling nut 110. Pump housing 104 has flanged portion 138 that engages end plate 152 of gear train assembly 12. Pump housing 104 is attached to gear train assembly 12 by fasteners 40.

The respective configurations of gear train assembly 12, drive assembly 14, and pump assembly 16 permit pump assembly 16 to be readily removed for maintenance and/or customizations of hydraulic power pack 10. To remove pump assembly 12, an operator removes fasteners 40 and disengages female spline 80 by translating pump assembly 16 along axis 78. Thereafter, maintenance can be performed on pump assembly 16 before reinstallation on to hydraulic power pack 10. Additionally, pump assembly 16 can be replaced with a different pump assembly equipped with hydraulic cylinders that have a different configuration than the pump assembly 16, thus altering the pressure and flow rate of working fluid delivered by hydraulic power pack 10.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

CLAIMS:

1. A gear train assembly for use in a modular hydraulic power pack to couple a drive assembly to a pump assembly, the gear train assembly comprising:

a gear train comprising:

an input gear configured to couple to the drive assembly; and

an output gear having a female spline at an inner diameter of the output gear that is configured to engage a male spline of the pump assembly;

a housing enclosing the gear train; and

a plurality of supports disposed between the gear train and the housing configured to radially and axially restrain the gear train relative to the housing; wherein the plurality of supports and the female spline permit the pump assembly to be disconnected from the gear train assembly and removed as a unit from the modular hydraulic power pack.

2. The gear train assembly of claim 1, wherein the female spline is configured to prevent transmission of loads substantially parallel to a rotational axis of the output gear.

3. The gear train assembly of claim 2, wherein the female spline forms a portion of a parallel key spline.

4. The gear train assembly of claim 1, wherein the input gear has a first plurality of teeth extending from an outer diameter of the input gear, and the output gear has a second plurality of teeth extending from an outer diameter of the output gear, and wherein the ratio of the second plurality of teeth divided by the first plurality of teeth is greater than 1.0.

5. The gear train assembly of claim 4, the gear train further comprising:

a shaft extending along a rotational axis of the input gear; and

an intermediate gear coupled to the shaft and adjacent to the input gear, wherein the intermediate gear is enmeshed with the output gear.

6. The gear train assembly of claim 5, wherein the gear train is a two-stage, reducing gear train.

7. The gear train assembly of claim 1 and further comprising:

a first plurality of fasteners configured to couple the housing to a drive assembly; and

a second plurality of fasteners configured to couple the housing to the pump assembly.

8. The gear train assembly of claim 5, the plurality of supports comprising:

a first plurality of bearings disposed between the shaft and the housing to radially restrain the shaft relative to the housing;

a second plurality of bearings disposed between axially-extending and opposing hubs of the output gear and the housing to radially restrain the output gear relative to the housing;

a first plurality of bushings axially restraining the input gear, the intermediate gear, and the shaft relative to the housing; and

a second plurality of bushings axially restraining the output gear relative to the housing.

9. A modular hydraulic power pack comprising:

a drive assembly comprising:

a motor;

a motor housing enclosing the motor; and

a first shaft having a drive pinion disposed at an end thereof;

a pump assembly comprising:

a screw that has a male spline at an end thereof;

a pump housing enclosing the screw; and

a thrust bearing restraining the ball screw relative to the pump housing in a direction substantially parallel to a rotational axis of the ball screw; and

a gear train assembly coupling the drive assembly to the pump assembly, the gear train assembly comprising:

a gear train housing enclosing the gear train assembly;

an input gear enmeshed with the drive pinion;

an output gear comprising;

a female spline at an inner diameter of the output gear enmeshed with the male spline of the screw; and

a hub extending from opposite faces of the output gear;

a second stage pinion axially adjacent to the input gear and enmeshed with the output gear;

a gear shaft extending along a rotational axis of the input gear and the second stage pinion, the gear shaft rotatably coupling the input gear to the second stage pinion;

wherein the pump assembly is removably attached to the gear train assembly.

10. The hydraulic power pack of claim 9 and further comprising:

a first plurality of bearings disposed between the gear shaft and the housing to radially restrain the gear shaft relative to the housing; and

a second plurality of bearings disposed between the hub and the housing to radially restrain the output gear relative to the housing.

11. The hydraulic power pack of claim 10 and further comprising:

a first plurality of bushings axially restraining the input gear, the second stage pinion, and the gear shaft relative to the housing; and

a second plurality of bushings axially restraining the output gear relative to the housing.

12. The hydraulic power pack of claim 9, wherein the male and female splines permit displacement of the ball screw relative to the output gear in an axial direction substantially parallel to a rotational axis of the output gear and restrain rotation of the ball screw relative to the output gear.

13. The hydraulic power pack of claim 9, wherein the gear train assembly is a two-stage, reducing gear train.

14. The assembly of claim 9 and further comprising:

a first plurality of fasteners coupling the gear train assembly to the drive assembly; and

a second plurality of fasteners coupling the gear housing to the pump housing.

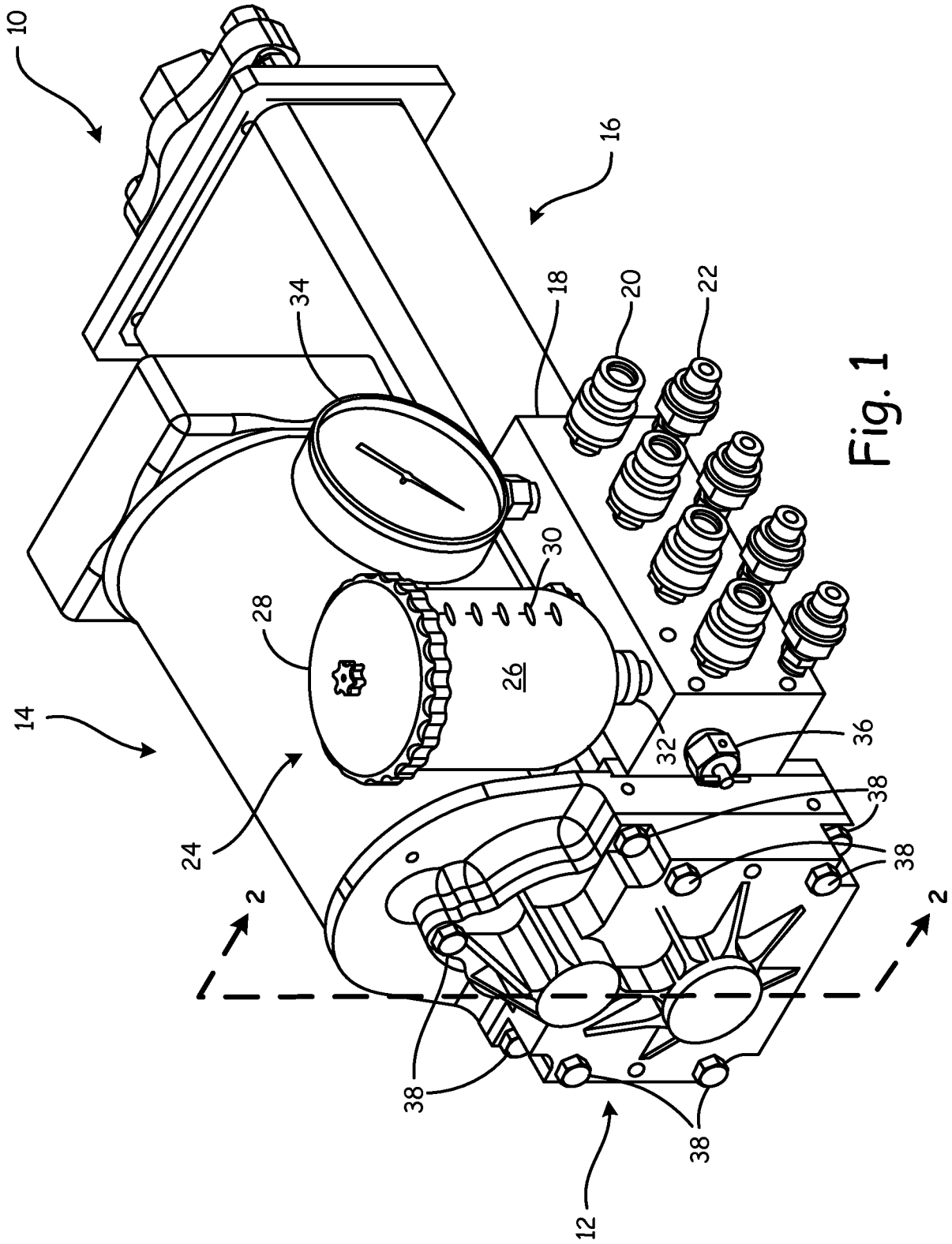
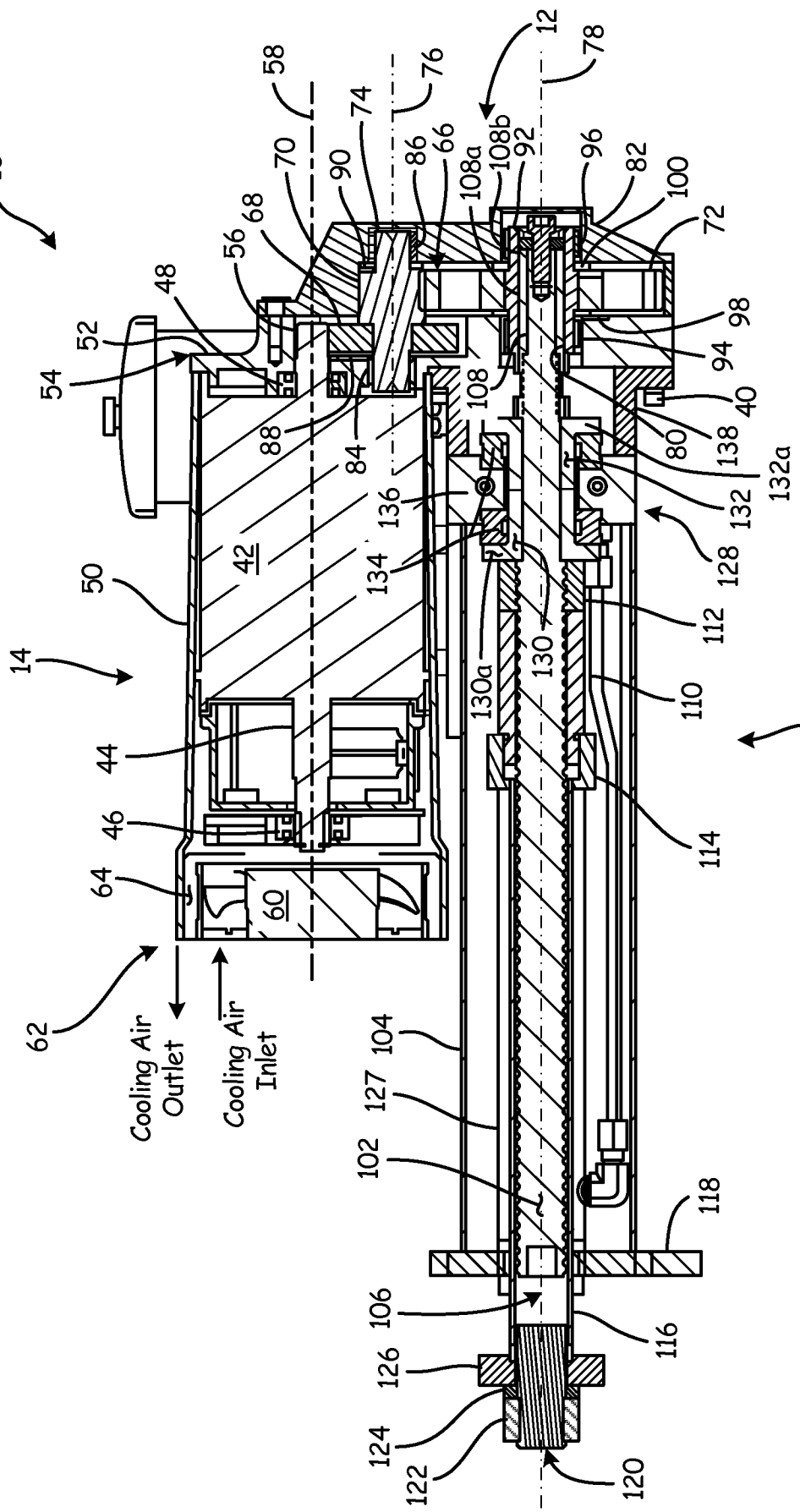


Fig. 1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Cooling Air Outlet
Cooling Air Inlet

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/040134

A. CLASSIFICATION OF SUBJECT MATTER

F04B 17/03(2006.01)i, F04B 9/02(2006.01)i

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)
F04B 17/03; B29C 47/60; F04B 35/04; B29C 45/43; B32B 1/00; F15B 7/00; F04B 9/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: pump, motor, shaft, gear, spline, bearing, busing, and fastener

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0148428 A1 (NISHIKAWA et al.) 14 June 2012 See paragraphs [0060]-[0072] and figure 5.	1-8
Y		9-14
Y	US 7223093 B2 (YOKOYA et al.) 29 May 2007 See column 3, lines 7-55 and figures 1-3.	9-14
A	US 2003-0024245 A1 (FULKS et al.) 06 February 2003 See paragraphs [0023]-[0033] and figure 1.	1-14
A	US 2013-0001829 A1 (HALTER et al.) 03 January 2013 See paragraphs [0029]-[0035] and figures 1-2b.	1-14
A	US 5993186 A (FLOYD et al.) 30 November 1999 See column 2, line 15 - column 3, line 36 and figures 1-5.	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"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	Date of mailing of the international search report
12 October 2015 (12.10.2015)	**13 October 2015 (13.10.2015)**

Name and mailing address of the ISA/KR
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
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