



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.06.2013 Bulletin 2013/25

(51) Int Cl.:
F01C 21/08 (2006.01) **F04C 2/344** (2006.01)
F04C 11/00 (2006.01) **F04C 15/00** (2006.01)

(21) Application number: **12250181.0**

(22) Date of filing: **14.12.2012**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **16.12.2011 US 201113328060**

(71) Applicant: **Goodrich Pump & Engine Control Systems, Inc.**
West Hartford, CT 06133-0651 (US)

(72) Inventors:
• **Dong, Xingen**
Farmington, Connecticut 06032 (US)
• **Paluszewski, Paul J.**
Meriden, Connecticut 06450 (US)
• **Desai, Mihir C.**
Yorba Linda, California 92887 (US)

(74) Representative: **Hargreaves, Timothy Edward Marks & Clerk LLP**
Aurora
120 Bothwell Street
Glasgow
G2 7JS (GB)

(54) **Multi-discharge hydraulic vane pump**

(57) Disclosed is a hydraulic vane pump that includes a pump body that defines an interior pumping chamber and an inlet port for allowing fluid to be provided to the interior pumping chamber and at least one discharge port for allowing pressurized fluid to be discharged from the interior pumping chamber. A cam ring that is disposed within the interior pumping chamber and defines a continuous peripheral cam surface; and a rotor is mounted for axial rotation within the interior pumping chamber. A plurality of vanes are mounted for radial movement within slots formed in the rotor. The pump also includes axially opposed first and second wear disks disposed within the interior pumping chamber. The first wear disk is a floating wear disk and has an outer periphery which is positioned radially inward of the cam surface and is adapted and configured to slide axially with respect to the cam surface, so as to provide for thermal expansion of the rotor and vanes. The second wear disk is positioned adjacent to a second end surface of the rotor.

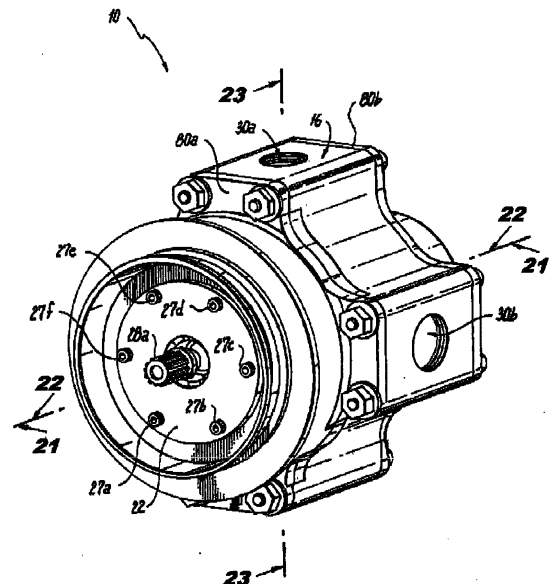


Fig. 1

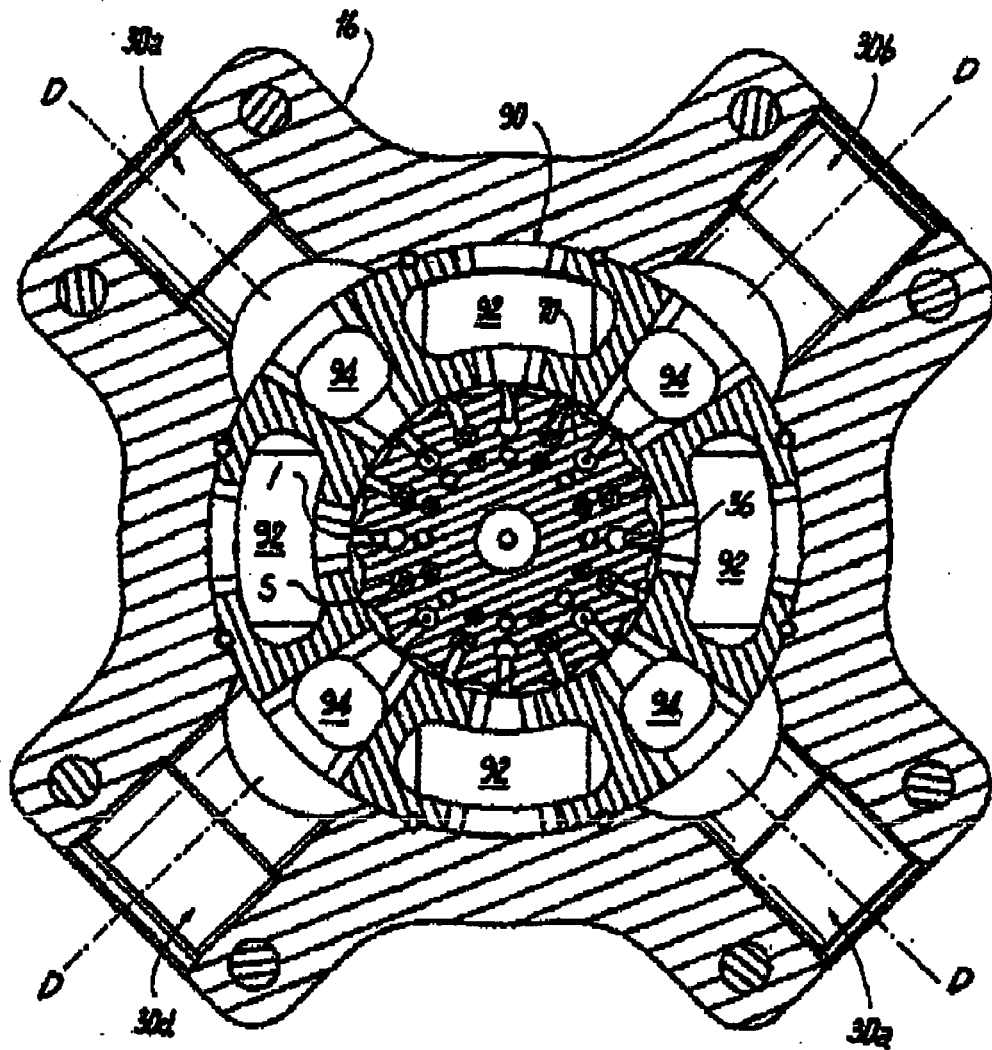


Fig. 20

Description

GOVERNMENT LICENSE RIGHTS

[0001] This invention was made with government support under contract number AATD W911 W6-06-D-0005-0004 awarded by the U.S. Army. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

1. Field of the Intention

[0002] The subject disclosure is directed to rotary vane pumps, and more particularly, to a balanced split discharge vane pump that provides a combined discharge flow for high fluid demand conditions and a first (primary) discharge flow for low fluid demand conditions, and still more particularly to a multi-discharge vane pump that has an inlet port and four discharge ports, includes a floating side wear disk and a cam ring with internal flow passages, and a rotor assembly with improved under-vane pumping features.

2. Description of Related Art

[0003] Rotary hydraulic vane pumps are well known in the art, as disclosed for example in U.S. Patent No. 4,274,817 to Sakamaki et al. and U.S. Patent No. 5,064,362 to Hansen. A typical rotary vane pump includes a circular rotor mounted for rotation within a larger circular pumping chamber. The centers of these two circles are typically offset, causing eccentricity. Vanes are mounted to slide in and out of the rotor to create a plurality of volume chambers or vane buckets that perform the pumping work. On the intake side of the pump, the vane buckets increase in volume. These increasing volume vane buckets are filled with fluid that is forced into the pumping chamber by an inlet pressure. On the discharge side of the pump, the vane buckets decrease in volume, forcing pressurized fluid out of the pumping chamber.

[0004] It is desirable to match the fluid displacement of a vane pump to the operating characteristics of the system with which the pump is to be associated. For example, the maximum displacement of a fuel pump should be coordinated with the maximum fuel requirements of the associated engine application. However, system requirements typically vary with operating conditions, so that a fixed displacement fuel pump that is designed as a function of the most demanding engine operating conditions may function with less than desired efficiency under other operating conditions.

[0005] In the case of a fuel pump associated with a gas turbine engine of an aircraft, fuel flow requirements, as quantified by pump displacement per rotational speed, under engine starting conditions greatly exceed fuel flow requirements during other less demanding engine operating conditions, such as cruise, idle, decent and taxi.

Various attempts have been made to improve fuel pump efficiency over the operating envelope of a gas turbine engine, by utilizing different valve arrangements at the pump outlet to meter a portion of the pump discharge to the engine as a function of engine demand. However, these prior art arrangements are typically complex and thus add cost to the pumping system. In other implementations, variable displacement pumps have been utilized to match pump output flow to system demand. However, these implementations are at the expense of pump size/weight and reliability because of an increase in pump radial/axial loading and the incorporation of additional moving parts.

[0006] U.S. Patent Application Publication No. 2010/0316507, entitled Split Discharge Vane Pump and Fluid Metering System Therefor, discloses a positive displacement vane pump that is adapted and configured to more closely match the operating characteristics of the system with which it is associated, as well as, a valving arrangement for effectively managing the flow of fluid from the pump depending upon the fluid demand conditions of the system with which it is associated. The disclosure of U.S. Patent Application Publication No. 2010/0316507 is hereby incorporated by reference in its entirety.

[0007] The pump disclosed in U.S. Patent Application Publication No. 2010/0316507 solves many of the problems noted above with respect to prior art pump constructions. However, there is need for a positive displacement vane pump design that further increases pumping efficiency over the operation range of fuel requirements and reduces component degradation by more effectively balancing the forces within the pumping chamber.

SUMMARY OF THE INVENTION

[0008] The present invention is directed to a hydraulic vane pump that includes, *inter alia*, a pump body that defines an interior pumping chamber and an inlet port for allowing fluid to be provided to the interior pumping chamber and at least one discharge port for allowing pressurized fluid to be discharged from the interior pumping chamber. The pump further includes a cam ring that is disposed within the interior pumping chamber and defines a continuous peripheral cam surface; and a rotor mounted for axial rotation within the interior pumping chamber and defining a pump axis. A plurality of circumferentially spaced apart radially extending vanes are mounted for radial movement within slots formed in the rotor, the plurality of vanes define an equal number of circumferentially spaced apart volume chambers which extend between an outer periphery of the rotor and the cam surface for carrying pressurized fluid. Still further, the pump includes axially opposed first and second wear disks disposed within the interior pumping chamber. The first wear disk has an outer periphery which is positioned radially inward of the cam surface and is adapted and configured to slide axially with respect to the cam surface, so as to provide for thermal expansion of the rotor and

vanes. The second wear disk is fixedly positioned adjacent to a second end surface of the rotor. However, as will be discussed below, the second wear disk can also be a floating disk (i.e., adapted for sliding in the axial direction).

[0009] In a preferred embodiment, the pump is a multi-discharge hydraulic vane pump and the pump body defines four radially-oriented discharge ports, each discharge port allowing pressurized fluid to be discharged from the interior pumping chamber.

[0010] It is envisioned that the first wear disk is biased towards the first end surface of the rotor using a spring element. Moreover, the first wear disk can be biased towards the first end surface of the rotor using pressurized fluid discharged from the volume chambers defined by the vanes.

[0011] In certain constructions of the present invention, the pump body further includes a rear side plate and the inlet port extends axially through the rear side plate to the interior chamber.

[0012] Preferably, the cam surface includes four quadrantal cam segments, wherein diametrically opposed cam segments have identical cam profiles, and each cam segment defines an inlet arc, a discharge arc and two seal arcs.

[0013] In a preferred embodiment, the cam ring includes a plurality of inlet chambers arranged and configured to receive fluid from the inlet port and distribute the fluid to the inlet arc of each cam segment. The cam ring can also include a plurality of discharge chambers which communicate with the discharge arc of each cam segment and are arranged and configured to facilitate the discharge of pressurized fluid from the interior pumping chamber.

[0014] It is presently preferred that each vane slot has an under-vane pocket for receiving pressurized fluid based on an angular position of the rotor. Additionally, in certain embodiments, the rotor includes a plurality of axially-extending under-vane passages, each under-vane passage communicating with an under-vane pocket through a connector passage.

[0015] Preferably, each wear disk includes flow passages for communicating fluid into the under-vane pockets and under-vane passages associated with each vane slot. The pressure of the undervane pocket is dependent on an angular position of the rotor. Preferably, the fluid in the rotor under-vane passage whilst positioned in the inlet arc segment is about equal to pump inlet pressure and the fluid in the rotor under-vane passage whilst positioned in the discharge arc segment is about equal to pump discharge pressure.

[0016] Certain constructions of the vane pump of present invention include a fluid metering system for extracting fluid flow from the discharge arcs of the four cam segments. It is envisioned that the metering system has a first operating condition in which fluid is extracted from the discharge arcs of all four cam segments and combined for delivery to a source of fluid demand. The fluid

metering system can also include a second operating condition wherein fluid is extracted from a first (primary) pair of diametrically opposed discharge arcs for delivery to a source of fluid demand and fluid from a second pair of diametrically opposed discharge arcs bypasses the source of fluid demand and returns to the pumping chamber.

[0017] The present invention is also directed to a multi-discharge hydraulic vane pump that includes, among other elements, a pump body that has an interior pumping chamber and defines a axially extending inlet port for allowing fluid to be provided to the interior pumping chamber and four radially-extending discharge ports for allowing pressurized fluid to be discharged from the interior pumping chamber. The vane pump further includes a cam ring disposed within the interior pumping chamber that defines a continuous peripheral cam surface and a rotor mounted for axial rotation within the interior pumping chamber that defines a pump axis. A plurality of circumferentially spaced apart and radially extending vanes are mounted for radial movement within slots formed in the rotor. The plurality of vanes define an equal number of circumferentially spaced apart volume chambers which extend between an outer periphery of the rotor and the cam surface for carrying pressurized fluid. The pump further includes axially opposed first and second wear disks which are disposed within the interior pumping chamber.

[0018] In a preferred embodiment, the first wear disk has an outer periphery which is positioned radially inward of the cam surface and is mounted for sliding movement with respect to the cam surface, so as to provide for thermal expansion of the rotor and vanes. The second wear disk is positioned adjacent to a second end surface of the rotor.

[0019] It is envisioned that the first wear disk is biased towards the first end surface of the rotor using a spring element. Moreover, the first wear disk can be biased towards the first end surface of the rotor using pressurized fluid discharged from the volume chambers defined by the vanes.

[0020] In certain constructions of the present invention, the pump body further includes a rear housing with an inlet port that extends axially through the rear side plate to the interior chamber.

[0021] Preferably, the cam surface includes four quadrantal cam segments, wherein diametrically opposed cam segments have identical cam profiles, and each cam segment defines an inlet arc, a discharge arc and two seal arcs.

[0022] In a preferred embodiment, the cam ring includes a plurality of inlet chambers arranged and configured to receive fluid from the inlet port and distribute the fluid to the inlet arc of each cam segment. The cam ring also includes a plurality of discharge chambers which communicate with the discharge arc of each cam segment and are arranged and configured to facilitate the discharge of pressurized fluid from the interior pumping

chamber.

[0023] It is presently preferred that each vane slot has an under-vane pocket for receiving either low inlet or discharging high outlet pressurized fluid based on an angular position of the rotor. Additionally, in certain embodiments, the rotor includes a plurality of axially-extending under-vane passages, each under-vane passage communicating with an under-vane pocket through a connector passage.

[0024] It is envisioned that each wear disk can include flow passages for communicating fluid into the under-vane pockets and under-vane passages associated with each vane slot. The pressure of the undervane pocket is dependent on an angular position of the rotor. Preferably, the pressurized fluid in the rotor under-vane passage whilst positioned in the inlet arc segment is about equal to pump inlet pressure and the fluid in the rotor under-vane passage whilst positioned in the discharge arc segment is about equal to pump discharge pressure.

[0025] Certain constructions of the vane pump of present invention include a fluid metering system for extracting fluid flow from the discharge arcs of the four cam segments. It is envisioned that the metering system has a first operating condition in which fluid is extracted from the discharge arcs of all four cam segments and combined for delivery to a source of fluid demand. The fluid metering system can also include a second operating condition wherein fluid is extracted from a first pair of diametrically opposed discharge arcs for delivery to a source of fluid demand and fluid from a second pair of diametrically opposed discharge arcs bypasses the source of fluid demand and returns to the pumping chamber.

[0026] The present invention is further directed to a hydraulic vane pump that includes, *inter alia*, a pump body that defines an interior pumping chamber, an inlet port for allowing fluid to be provided to the interior pumping chamber and at least one discharge port for allowing pressurized fluid to be discharged from the interior pumping chamber. The hydraulic vane pump further includes a cam ring disposed within the interior pumping chamber that defines a continuous peripheral cam surface, the cam ring also defining a plurality of inlet chambers and discharge chambers. The inlet chambers are arranged and configured to receive fluid from the inlet port and to distribute the fluid to the interior pumping chamber and the discharge chambers communicate with the interior pumping chamber and are arranged and configured to facilitate the discharge of pressurized fluid from the interior pumping chamber.

[0027] A rotor is mounted for axial rotation within the interior pumping chamber and defines a pump axis. A plurality of circumferentially spaced apart and radially extending vanes are mounted for radial movement within slots formed in the rotor. The plurality of vanes define an equal number of circumferentially spaced apart volume chambers which extend between an outer periphery of the rotor and the cam surface for carrying pressurized

fluid. Each vane slot has an under-vane pocket for communicating fluid. The pressure in the undervane pockets are dependent on an angular position of the rotor.

[0028] Axially opposed first and second wear disks are disposed within the interior pumping chamber, the first wear disk has an outer periphery which is positioned radially inward of the cam surface and is axially biased towards a first end surface of the rotor, so as to provide for thermal expansion of the rotor and vanes. The second wear disk is positioned adjacent to a second end surface of the rotor. Preferably, each wear disk includes flow passages for communicating fluid into the under-vane pockets associated with each vane slot. The pressure of the undervane pockets is dependant on an angular position of the rotor.

[0029] These and other features and benefits of the subject invention and the manner in which it is assembled and employed will become more readily apparent to those having ordinary skill in the art from the following enabling description of the preferred embodiments of the subject invention taken in conjunction with the several drawings described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] So that those skilled in the art to which the subject invention appertains will readily understand how to make and use the methods, devices and systems of the subject invention without undue experimentation, preferred embodiments thereof will be described in detail hereinbelow with reference to certain figures, wherein:

[0031] FIG. 1 is a perspective view of a multi-discharge pump assembly which has been constructed in accordance with a preferred embodiment of the present invention;

[0032] FIG. 2 is a partially exploded perspective view of the pump assembly of FIG. 1 in which a front side plate has been removed for ease of illustration;

[0033] FIG. 3 is an exploded perspective view of the cam ring, the rotor assembly, the annular spacer and the rear side plate used in the pump assembly of FIG. 1;

[0034] FIGS. 4 provides an end view of a rear side plate used in the pump assembly of FIG. 1;

[0035] FIG. 5 provides a cross-sectional view of the rear side plate shown in FIG. 4 taken along cut line 5-5;

[0036] FIG. 6 provides a cross-sectional view of the rear side plate shown in FIG. 4 taken along cut line 6-6;

[0037] FIG. 7 is an exploded view of a portion of the pump assembly of FIG. 1 which illustrates the front side fixed wear plate, the rotor assembly, the cam ring and the rear side sliding wear plate;

[0038] FIG. 8 is a perspective view of the rotor assembly used in the pump assembly of FIG. 1;

[0039] FIG. 9 is a cross-sectional view of the rotor assembly of FIG. 8 taken along cut line 9-9;

[0040] FIG. 10 is a perspective view of the cam ring used in the pump assembly of FIG. 1;

[0041] FIG. 11 is an end view of the cam ring of FIG. 10;

[0042] FIG. 12 provides a perspective view of the rear side floating disk used in the pump assembly of FIG. 1;

[0043] FIG. 13 is a front end view of the floating wear disk of FIG. 12;

[0044] FIG. 14 is a rear end view of the floating wear disk of FIG. 12;

[0045] FIG. 15 is a cross-sectional view taken along cut line 15-15 of the floating wear disk of FIG. 12;

[0046] FIG. 16 provides a perspective view of the front side fixed wear disk used in the pump assembly of FIG. 7;

[0047] FIG. 17 is a front end view of the fixed wear disk of FIG. 16;

[0048] FIG. 18 is a rear end view of the fixed wear disk of FIG. 16;

[0049] FIG. 19 is sectional view of the pump assembly shown in FIG. 1 which illustrates that when the vanes are within the seal arc, the under-vane cavities are connected to pump discharge passages;

[0050] FIG. 20 is a cross-sectional view of the pump assembly shown in FIG. 1 taken along cut line 20-20 in FIG. 19;

[0051] FIG. 21 is sectional view of the pump assembly shown in FIG. 1 taken along cut line 21-21 which illustrates that when the vanes are within the discharge ramp/arc, the over-vane and under-vane cavities are connected to pump discharge passages;

[0052] FIG. 22 is sectional view of the pump assembly shown in FIG. 1 taken along cut line 22-22 which illustrates that when the vanes are within the inlet ramp/arc, the over-vane and under-vane cavities are connected to pump inlet passages; and

[0053] FIG. 23 provides a cross-sectional view of the rotor assembly and a portion of the cam ring.

[0054] These and other aspects of the subject invention will become more readily apparent to those having ordinary skill in the art from the following detailed description of the invention taken in conjunction with the drawings.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0055] Disclosed herein are detailed descriptions of specific embodiments of the devices, systems and methods of the present invention. It will be understood that the disclosed embodiments are merely examples of the way in which certain aspects of the invention can be implemented and do not represent an exhaustive list of all of the ways the invention may be embodied. Indeed, it will be understood that the systems, devices, and methods described herein may be embodied in various and alternative forms. The figures are not necessarily to scale and some features may be exaggerated or minimized to show details of particular components. Well-known components, materials or methods are not necessarily described in great detail in order to avoid obscuring the present disclosure. Any specific structural and functional details disclosed herein are not to be interpreted as lim-

iting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the invention.

[0056] For ease of description, the components of this invention are described in an upright operating position, and terms such as upper, lower, front, rear, horizontal, etc., are used with reference to this position. It will be understood, however, that the components of this invention may be manufactured, stored, transported, used, and sold in an orientation other than the position described.

[0057] Figures illustrating the components show some mechanical elements that are known and will be recognized by one skilled in the art. The detailed descriptions of such elements are not necessary to an understanding of the invention, and accordingly, are herein presented only to the degree necessary to facilitate an understanding of the novel features of the present invention.

[0058] Referring now to the drawings wherein like reference numerals identify similar structural features or elements of the subject invention, there are illustrated in FIG. 1 an embodiment of the hydrostatically-balance, multi-discharge hydraulic vane pump of the present invention designated generally by reference numeral 10 which includes a cartridge assembly pumping element (item 90 in Fig. 7). The cartridge assembly 90 is configured to fit within a reusable housing (annular space 16). In other words, the pump element 90 can be readily replaced when worn or in need of repair. FIGS. 2 through 18 provide views of the various component parts that form the pump element 90 and FIGS. 19 through 23 provide cross-sectional and elevational views for pump assembly 10 in a variety of operating configurations.

[0059] Pump assembly 10 includes a single inlet port 24 (see FIGS. 19-22) for admitting low pressure fluid into the pump assembly 10. Pump assembly 10 also includes four discharge ports 30a-d for discharging pressurized fluid from the pump assembly 10. Discharge ports 30a and 30c diametrically oppose each other. Similarly, discharge ports 30b and 30d diametrically oppose each other. Normally, 30a/30c or 30b/30d for one of two pumps.

[0060] By passing through the pump assembly 10, the low pressure fluid becomes high pressure fluid and exits the pump assembly through either two diametrically opposed discharge ports 30a-d or through all of the discharge ports. The manner in which the low pressure fluid proceeds from the inlet port 24 into the interior pump chamber 42, is pressurized and is supplied to the discharge ports 30a-d will be discussed in detail herein below. By having diametrically opposed discharge ports 30a-d, the forces generated in the pumping process thereby effectively cancel to provide a balanced pump assembly 10.

[0061] The pump assembly 10 also includes fixed front and rear side plates 80s, 80b, which are separated from one another by an annular spacer 16. The inlet port 24 is formed in the rear side plate 80b. The discharge ports 30a-30d are formed in the annular spacer 16.

[0062] An end plate 22 is fixed to the front side plate 80a using a series of bolts 27a-f and defines an axial passageway 26 through which a drive shaft 28a passes to attach to a rotor assembly 70. The front and rear side plates 80a, 80b, along with the annular spacer 16, combine to form an interior or pumping chamber 42 that houses a cam ring 90, a floating side wear disk 50, a fixed side wear disk 60 and the rotor assembly 70 (see FIG. 3).

[0063] Referring to FIG. 2, a perspective view of the pump assembly 10 is shown with the front side plate 80a removed to illustrate the rotor assembly 70 and the cam ring 90 housed in the pumping chamber 42 and having a front end abutting the fixed side wear disk 60. FIG. 3 provides an additional exploded perspective view in which the cam ring 90, fixed side wear disk 60, floating wear disk 50 and the rotor assembly 70 have been removed from within the interior pumping chamber 42.

[0064] The rotor assembly 70, which is best viewed in FIGS. 8 and 9, is mounted on a drive shaft 28b for axial rotation within the pumping chamber 42. The rotor assembly is supported for rotation within the pumping chamber 42 by two journal bearings which are associated with the side wear disks 50/60. As shown in FIG. 19, rotor drive shaft 28b engages with drive shaft 28a which extends outside of the front side plate 80a.

[0065] Rotor assembly 70 includes a rotor body 71, which fits within a pumping chamber surface 35 defined by cam ring 90 (best shown in FIG. 11). The rotor body 71 includes a plurality of radially outwardly acting vane elements 36 which normally contact the elliptical pumping chamber surface 35. As described in more detail below, a plurality of circumferential vane buckets or volume chambers 44 are formed between the rotor body 71, the elliptical pumping chamber surface 35, the vane assemblies 36 and the wear disks 50/60 (see FIG. 20).

[0066] For each vane element 36, rotor body 71 includes a vane slot 38 into which the vane element is slidably received, an axially extending under-vane pumping pocket 73 and an axially extending under-vane pumping passage 75. Radially extending, but angled, connector passages 77, allow fluid to communicate between the under-vane pumping pocket 73 and under-vane pumping passage 75. The manner in which the under-vane pumping occurs and the benefits associated with the configuration of the under-vane pumping of the present invention will also be described below.

[0067] Referring now to FIGS. 4 through 6, which provide several views of rear housing plate 80b. Eight through holes 82 are provided in the outer flanges of the front and rear housing plates 80a/80b which allow the rear housing plate 80b and the front housing plate 80a to be secured to the annular spacer 16 using through bolts and associated nuts (see FIG. 1). As discussed above, the axial inlet port 24 for the pump assembly 10 is formed in the rear side plate 80b and branches off into four diametrically opposed angled inlet channels 84. These inlet channels 84 can also be viewed in FIG. 3 and as will be discussed below are arranged and config-

ured so as to distribute the incoming fluid into four axially extending inlet chambers 92 formed in cam ring 90.

[0068] Referring now to FIGS. 10 and 11, in addition to the axially extending inlet chambers 92, cam ring 90 also defines axially extending discharge chambers 94. Still further, the outer periphery 96 of the cam ring 90 also includes a plurality of access slots 108 which are used to enable the formation of radially extending ports 104/106 which extend through the inner wall 102 of the cam ring 90 to the pumping chamber surface 35. Ports 104 extend radially inward from the inlet chambers 92 and ports 106 extend radially inward from the discharge chambers 94. The purpose of the flow ports 104/106 will also be discussed below.

[0069] The cam ring 90 is also provided with a number of seal grooves. For example, the outer periphery 96 of the cam ring 12 includes a plurality of seal grooves 98 which are adapted and configured for receiving linear sealing elements. Each end of the cam ring 90 also includes a circular seal groove 99 and the pumping chamber surface 35 includes front and rear circumferential seal grooves 97. Those skilled in the art will readily appreciate the seals inserted into the seal grooves 97/98/99 are designed to prevent cross port leakage throughout the pump assembly 10.

[0070] Referring now to FIGS. 12 through 15 where there is illustrated floating wear disk 50. As shown in FIG. 19, unlike prior art wear disks, which are fixedly positioned outside and adjacent to the end of the cam ring, floating wear disk 50 is positioned entirely within the inside profile of the cam ring 90 and is adapted for sliding in an axial direction to allow for thermal expansion of the rotor assembly during operation. However, unlike prior art devices wherein the axial gap between the wear disk and the rotor must be minimized in order to prevent cross port leakage, in pump assembly 10 it is the circumferential gap between the floating wear disk 50 and the pumping chamber surface which must be sealed. Since the circumferential gap is much less impacted by thermal expansion during operation of the pump, it is easier to maintain the seal in this location.

[0071] Like cam ring 90, floating wear disk 50 includes a plurality of fluid ports which allow fluid to communicate with pump assembly 10. For example, eight radial holes 52 are provided which extend from the outer periphery of the floating wear disk 50. Four of the radial holes 52 connect with four axially extending discharge fluid ports 54 and the other four radial holes 52 connect with four axially extending inlet fluid ports 56. As will be discussed in detail below, the discharge fluid ports 54 are used to allow pressurized discharge fluid to be provided to the under-vane slots and under-vane passages to be used for under-vane pumping and the inlet fluid ports 56 are used to allow low pressure inlet fluid to be provided to the under-vane slots and under-vane passages to be used for under-vane pumping.

[0072] The floating wear disk 50 is also provided with a journal bearing 58 which supports one end of the rotor

assembly 70 within the pumping chamber 52. Four seal grooves 53 are provided on the rear face of the floating wear disk 50 and are adapted for receiving a face seal. Additionally, eight spring cavities 55 are formed in the rear face of the floating wear disk 50 and contain a spring element or biasing mechanism for urging the floating wear disk 50 in the direction of the rotor assembly 70. Moreover, a small hole 59 extends from each of the discharge fluid ports 54 to the rear face of the floating wear disk 50. As a result, pressurized discharge fluid is supplied to the back side of the floating wear disk 50 and further urges/biases the floating wear disk 50 in the direction of the rotor assembly 70. The configuration and location of the seal grooves 53 defines a load area against which the pressurized discharge fluid works in order to urge the floating wear disk 50 towards the rotor assembly 70. As a result, the amount of pressure applied to the back side of the wear disk 50 can be adjusted by adjusting the load area upon which the discharge fluid works.

[0073] Referring now to FIGS. 16 through 18 which illustrate the fixed side wear disk 60 used in the pump assembly 10 of the present invention. Like the floating wear disk 50, the fixed side wear disk 60 includes a journal bearing 68 and a plurality of radial holes 62. Four axially extending discharge fluid ports 64 communicate with four of the radial holes 62 and four radially extending inlet fluid ports 66 communicate with the remaining four radial holes 62. Similar to the floating wear disk 50, discharge fluid ports 64 and inlet fluid ports 66 are used to provide fluid in support of under-vane pumping.

[0074] The back side of the fixed side wear disk 60 includes circular pressure relief grooves 67a/67b and four radially extending pressure relief grooves 69a-d. It should be noted that both the floating side wear disk and the fixed side wear disk include slots for receiving a pin which prevents the disks 50/60 from rotating with respect to the cam ring 90.

[0075] Referring now to FIGS. 19 through 23 which illustrate the arrangement of the component parts used in pump assembly 10 and the manner in which the pump assembly operates to increase the pressure of the inlet fluid. In operation, fluid is received in inlet port 24 and is diverted into the four inlet channels 84. The four inlet channels 84 provide the fluid to the four axially extending inlet chambers 92 formed in the cam ring 90. From the inlet chambers 92 the fluid is directed radially inward through the radially extending inlet ports 104. The end two ports 104 provide fluid to four radial holes 52/62 formed in the wear disks 50 and 60 respectively, and this fluid is used for under-vane pumping. The fluid proceeding through the remaining ports 104 formed in the cam ring 90 is supplied into vane buckets 44 which are in the four inlet arc regions "I" shown in FIG. 23. As the rotor assembly 70 rotates the fluid is displaced and exits the vane buckets 44 in the discharge arc region "D" through the interior-most ports 106 formed in the cam ring 90 and is received into the four axially extending discharge

chambers 94. A portion of the pressurized fluid contained in the discharge chamber 94 is provided to the discharge fluid ports 54/64 of the wear disks 50/60 via radial holes 52/62 and is used for under-vane pumping. The remaining pressurized fluid contained with the four axially extending discharge chambers 94 formed in the cam ring 90 is provided to the four discharge ports 30a-d of the pump assembly 10.

[0076] FIG. 19 is sectional view of the pump assembly shown in FIG. 1 which illustrates that when the vanes 36 are within the seal are "S", the under-vane slot 75 and the under-vane passage 73 are connected to pump discharge passages which are formed in the wear disks 50/60 and the cam ring 90. FIG. 20 is a cross-sectional view of the pump assembly shown in FIG. 1 taken along cut line 20-20 in FIG. 19.

[0077] FIG. 21 is sectional view of the pump assembly shown in FIG. 1 which illustrates that when the vanes 36 are within the discharge ramp/are "D", the over-vane 44 and under-vane cavities 73/75/77 are connected to pump discharge passages which are formed in the wear disks 50/60 and the cam ring 90.

[0078] Lastly, FIG. 22 is sectional view of the pump assembly shown in FIG. 1 which illustrates that when the vanes 36 are within the inlet ramp/are "I", the over-vane and under-vane cavities are connected to pump inlet passages which are formed in the wear disks 50/60 and the cam ring 90.

[0079] Typically, in prior art vane pumps, the wear disks are fixedly mounted within the interior pumping chamber and abut the axial ends of the cam ring and rotor blade. As shown in these figures, the front side wear disk 50 is a floating wear disk which is located radially inside of the pumping chamber surface 35 defined by the cam ring 90.

[0080] Previously disclosed vane pump designs usually have a fixed axial clearance between the wear disk and the rotor. Moreover, the wear plates/disks at both side of the rotor/vane are fixed. For a fixed axial clearance design, the longer the rotor, the more axial clearance is needed considering free thermal expansion of the rotor and vanes. At high operating temperatures, the amount of available clearance between the rotor and wear disks could be significantly reduced due to rotor/vane expansion. As a result, mechanical galling and premature wear could occur at rotor ends if the axial clearance is not sufficient.

[0081] Moreover, as discussed previously, cross-port leakage occurs due to above described fixed axial clearance. Excessive leakage could then take place at high pump operating pressures. This leakage could have significant effect on the minimum allowable operation speed of the pump, in addition to significant energy loss of the pump. In other terms, the pump could have little or no discharge flow due to its excessive internal re-circulated cross-port leakage at a low input speed.

[0082] Therefore, it is preferred to have a vane pump with at least one pressure compensated side wear disk.

In the present invention, during pump operation, the pressure overbalanced side wear disk 50 is subject to a net clamping force that pushes the wear disk against the rotor/vanes (rotating group) tightly. This net force comes from mechanical spring force and/or hydraulic pressure acting on the back side of the floating wear disk 50 at the side opposite to the rotor 70. Usually, the higher the operating pressure, the higher the net clamping force. In a pump of good design, the clamping force closes the axial gap and squeezes the oil film between rotor and the wear disk to a minimum film thickness without mechanical contact between two parts that rotate close to each other.

[0083] To allow the floating wear disk 50 to move freely inside the cam ring 90 as a result of the above described net biased force, the outer shape of the wear disk 50 generally has the same shape (with adequate radial clearance for free relative movement) as the inner pumping chamber surface 35 of the cam ring 90. Thus, the floating wear disk 50 requires precision manufacturing similar to the cam ring inner diameter 35.

[0084] Typically, the inner pumping chamber surface of a cam ring has an elliptical shape for a single balance (dual action) fixed displacement vane pump. As shown in FIG. 23, in the present invention, the cross-section of the inner pumping chamber surface 35 is close to a circle because it has two balanced pumps in a same pumping element. Alignment pins could be used to ensure proper orientation of the wear disk and the cam profile.

[0085] Those skilled in the art will readily appreciate that the fixed side wear disk 60 could also be a floating wear disk if cost is not a concern. Preferably, both disks 50/60 are made of steel, alumiaum, or other light weight materials for weight reduction and have hard coated layers applied on the wear surfaces (rotor side). It also should be appreciated that the back side of the floating wear disk 50 is connected to corresponding pump discharge pressure all the time.

[0086] When a rotor rotates, vanes are expected to maintain contact with the inner surface of the cam ring. Since the inner surface of the cam ring has a varying radius at different angular positions, each vane, which behaves as a piston, will slide into and out of the rotor inside the rotor vane slot. This radial movement of the vane stokes fluid into and out the cavity beneath it. To let each vane work as a positive displacement piston pump, a porting device is needed. The porting device assures that when the cavity volume increases, the under-vane pumping passages are linked to a pump inlet pressure; and conversely, when the bucket volume is reduced, the under-vane pumping passages are linked to its corresponding pump discharge line.

[0087] Conventional vane pumps usually incorporate flow passages that directly connect an under-vane cavity to corresponding over-vane volume chambers. Thus, under-vane cavities can be linked to the inlet and discharge ports of the pump at the same time as their corresponding over-vane volume chambers. Those flow passages could be inside the rotor or use the interface between rotor and

the side wear plate. The disadvantage of the conventional design is that there are significant dynamic pressure losses along and through the flow passages and cavitation damage could result in these areas when the pump is operated at very high speed.

[0088] Vane pump assembly 10 provides a separate porting mechanism to link inlet and discharge ports of each pump (over-vane) to its corresponding under-vane cavities. When a cavity volume increases, it is linked to pump inlet pressure. When the cavity is reduced, it is linked to a corresponding discharge line.

[0089] Over vane volume chambers (16 total for pump assembly 10) are separated by vane/cam sealing. As shown in FIG. 19 when a vane 36 is sweeping on the seal arc "S" (the constant radius portion of the cam ring profile located between inlet and discharge ports), its under-vane passage 73 and under-vane slot/pocket 75 are linked to a pump discharge pressure port to assure that the vane 36 can be pushed out by under-vane hydraulic pressure forces. When a vane 36 is sweeping on the inlet ramp "I", as shown in FIG. 22, its under-vane passage 73 and under-vane slot 75 are connected to inlet pressure. When a vane 36 is sweeping the discharge ramp, as shown in FIG. 21, its under-vane passage 73 and under-vane slot 75 are connected to its corresponding discharge line. As a result, the pressure ports on the wear disks are longer in the circumferential direction in the discharge ports 54/64 than the inlet ports 56/66.

[0090] As discussed previously, there are radial holes 52/62 on the outer surfaces of the wear disks 50/60. Those radial holes 52/62 are used to connect the under-vane passage 73 and under-vane slot 75 (for under-vane pump porting) to pump inlet lines 92 and discharge lines 94, which are integrated into the cam ring 90.

[0091] Vanes pump under-vane cavity fluid at very rapid speed. To avoid excessive pressure build up or de-compression due to resistance of the under-vane cavities and flow passages, unlike a conventional design, which has only one axial slot to connect under-vane cavity to pump system ports or over-vane volume chamber, the pump assembly 10 has both an under-vane passage 73 and an under-vane slot 75 for a single under-vane pumping element. This arrangement reduces the pressure loss inside the under-vane cavity and flow passages.

[0092] The outer axial slot 75 is a primary one and the inner axial passage 73 is the second link to under-vane cavities and pump ports. The second passage 73 is linked to the primary slot inside the rotor via a number of radial connector passages 77. Those radial connector passages 77 are slanted with an angle to reduce the energy loss of merging flow.

[0093] As will be readily appreciated, pump assembly 10 is a split discharge pump and is essentially a main fuel pump that consists of four separate pumps. Each pump can discharge flow both from over-vane volume chambers and under-vane volume chambers. All volume chambers need separate timely porting to assure volume

chambers are connected to an inlet line when their volume is expanding and connected to a pump discharge line when its volume is contracting.

[0094] As discussed above, the cam ring 90 is designed to receive fluid from a common pump inlet 24 (four pumps share the same pump inlet) and it ports it to the inlet ports 56/66 of the wear disk, along with performing porting for the over-vane volume chambers. In addition, it receives discharge flow from the wear plates 56/60 and combines the flow with corresponding over-vane discharge flow and then provides for discharge from one of the four corresponding discharge ports 94 in the cam ring.

[0095] To assure the minimum timing error for over-vane porting, the angular location of the ports on the inner surface of the cam ring is very critical and requires precision manufacturing. To reduce the manufacturing cost, these ports are machined from the outer surface of the cam ring 90. When the cam ring is inserted into its housing/annular space 16, some construction openings on the outer surface will be covered by the inner surface of the annular spacer 16. As discussed previously, multiple seal cords are used to seal circumferential cross-port leakage between the cam ring and the housing.

[0096] Those skilled in the art will readily appreciate that the cam ring 90 could have been designed differently with multiple pieces for ease of manufacturing. For instance, a hardened sleeve/ring could be used as vane running wear surface and inserted into a separate block inclusive of the flow ports, thereby simplifying manufacturing of the cam running surface and the flow passages.

[0097] Moreover, unlike prior vane pump constructions, vane pump assembly 10 includes single inlet port 24 oriented in the axial direction and multiple discharge ports 30a-30d oriented in the radial direction. There are a total four vane pumps for this split-discharge vane pump. All four pumps share the same pump inlet volume. For each pump, the over-vane volume chamber discharges flow into the cam ring. There, flow merges with the discharge flow from its corresponding under-vane cavity. Then, the total flow is expended from the pump from a pump discharge port. There are total of four discharge ports, one for each pump.

[0098] To form two balanced dual action vane pumps, the flow from two diagonally opposite discharge ports of the main pump could be combined by external plumbing. Alternatively the two ports could be linked internally inside a main pump housing by design, along with necessary control valves, as illustrated in U.S. Patent Application Publication No. 2010/0316507, the disclosure of which is incorporated by reference.

[0099] While the subject invention has been described with respect to preferred embodiments, those skilled in the art will readily appreciate that changes and modifications may be made thereto without departing from the spirit and scope of the subject invention as defined by the appended claims.

Claims

1. A hydraulic vane pump, comprising:

- a) a pump body including an interior pumping chamber and defining an inlet port for allowing fluid to be provided to the interior pumping chamber and at least one discharge port for allowing pressurized fluid to be discharged from the interior pumping chamber,
- b) a cam ring disposed within the interior pumping chamber and defining a continuous peripheral cam surface;
- c) rotor mounted for axial rotation within the interior pumping chamber and defining a pump axis;
- d) a plurality of circumferentially spaced apart radially extending vanes mounted for radial movement within slots formed in the rotor, the plurality of vanes defining an equal number of circumferentially spaced apart volume chambers which extend between an outer periphery of the rotor and the cam surface for carrying pressurized fluid; and
- e) axially opposed first and second wear disks disposed within the interior pumping chamber, the first wear disk having an outer periphery which is positioned radially inward of the cam surface and is adapted and configured to slide axially with respect to the cam surface, so as to provide for thermal expansion of the rotor and vanes, and the second wear disk being positioned adjacent to a second end surface of the rotor.

2. A hydraulic vane pump as recited in Claim 1, wherein the vane pump is a multi-discharge hydraulic vane pump and the pump body defines four radially-oriented discharge ports, each port allowing pressurized fluid to be discharged from the interior pumping chamber.

3. A hydraulic vane pump as recited in Claim 1, wherein at least one of a) and b):-

- a) the first wear disk is biased towards the first end surface of the rotor using a spring element towards the first end surface of the rotor;
- b) the first wear disk is biased towards the first end surface of the rotor using pressurized fluid discharged from the volume chambers defined by the vanes.

4. A hydraulic vane pump as recited in Claim 1, wherein the pump body further includes a rear housing plate and the inlet port extends axially through the rear housing plate to the interior chamber.

5. A hydraulic vane pump as recited in Claim 1, wherein the cam surface includes four quadrantal cam segments, wherein diametrically opposed cam segments have identical cam profiles, and each cam segment defines an inlet arc, a discharge arc and two seal arcs. 5
6. A hydraulic vane pump as recited in Claim 5, wherein at least one of a) and b):- 10
- a) the cam ring includes a plurality of inlet chambers arranged and configured to receive fluid from the inlet port and distribute the fluid to the inlet arc of each cam segment; 15
- b) the cam ring includes a plurality of discharge chambers which communicate with the discharge arc of each cam segment and are arranged and configured to facilitate the discharge of pressurized fluid from the interior pumping chamber. 20
7. A hydraulic vane pump as recited in Claim 1, wherein each vane slot has an under-vane pocket for receiving fluid and the pressure of the under-vane pocket is dependent on an angular position of the rotor. 25
8. A hydraulic vane pump as recited in Claim 7, wherein the rotor includes a plurality of axially-extending under-vane passages, each under-vane passage communicating with an under-vane pocket through a connector passage, and 30
- optionally:- 35
- each wear disk includes flow passages for communicating fluid into the under-vane pockets and under-vane passages associated with each vane slot and the pressure of the under-vane pocket is dependent on an angular position of the rotor.
9. A hydraulic vane pump as recited in Claim 7, wherein at least one of a) and b):- 40
- a) the pressure of the fluid in the rotor under-vane passage whilst positioned in the inlet arc segment is about equal to pump inlet pressure; 45
- b) the pressure of the fluid in the rotor under-vane passage whilst positioned in the discharge arc segment is about equal to pump discharge pressure.
10. A hydraulic vane pump as recited in Claim 5, further comprising a fluid metering system for extracting fluid flow from the discharge arcs of the four cam segments. 50
11. A hydraulic vane pump as recited in Claim 10, wherein at least one of a) and b):- 55
- a) the fluid metering system has a first operating condition in which fluid is extracted from the discharge arcs of all four cam segments and combined for delivery to a source of fluid demand; 5
- b) the fluid metering system has a second operating condition wherein fluid is extracted from a first pair of diametrically opposed discharge arcs for delivery to a source of fluid demand and fluid from a second pair of diametrically opposed discharge arcs bypasses the source of fluid demand and returns to the pumping chamber.
12. A multi-discharge hydraulic vane pump, comprising:
- a) a pump body including an interior pumping chamber and defining an axially extending inlet port for allowing fluid to be provided to the interior pumping chamber and four discharge ports for allowing pressurized fluid to be discharged from the interior pumping chamber; 10
- b) a cam ring disposed within the interior pumping chamber and defining a continuous peripheral cam surface; 15
- c) rotor mounted for axial rotation within the interior pumping chamber and defining a pump axis; 20
- d) a plurality of circumferentially spaced apart radially extending vanes mounted for radial movement within slots formed in the rotor, the plurality of vanes defining an equal number of circumferentially spaced apart volume chambers which extend between an outer periphery of the rotor and the cam surface for carrying pressurized fluid; and 25
- e) axially opposed first and second wear disks disposed within the interior pumping chamber. 30
13. A multi-discharge hydraulic vane pump as recited in Claim 12, wherein the first wear disk has an outer periphery which is positioned radially inward of the cam surface and is mounted for sliding movement with respect to the cam surface, so as to provide for thermal expansion of the rotor and vanes, and the second wear disk being positioned adjacent to a second end surface of the rotor. 35
14. A multi-discharge hydraulic vane pump as recited in Claim 13, wherein at least one of a) and b):- 40
- a) the first wear disk is biased towards the first end surface of the rotor using a spring element towards the first end surface of the rotor; 45
- b) the first wear disk is biased towards the first end surface of the rotor using pressurized fluid discharged from the volume chambers defined by the vanes. 50
15. A multi-discharge hydraulic vane pump as recited in Claim 12, wherein at least one of a) and b):- 55

- a) the pump body further includes a rear housing plate and the inlet port extends axially through the side plate towards the interior chamber;
b) the cam surface includes four quadrantal cam segments, wherein diametrically opposed cam segments have identical cam profiles, and each cam segment defines an inlet are, a discharge arc and two seal ares.
16. A multi-discharge hydraulic vane pump as recited in Claim 12, wherein:-
the cam ring includes a plurality of inlet chambers arranged and configured to receive fluid from the inlet port and distribute the fluid to the inlet are of each cam segment; and/or
the cam ring includes a plurality of discharge chambers which communicate with the discharge are of each cam segment and are arranged and configured to facilitate the discharge of pressurized fluid from the interior pumping chamber; and/or
17. A multi-discharge hydraulic vane pump as recited in Claim 12, wherein each vane slot has an under-vane pocket for receiving fluid and the pressure in the under-vane pocket is dependent on an angular position of the rotor.
18. A multi-discharge hydraulic vane pump as recited in Claim 17, wherein the rotor includes a plurality of axially-extending under-vane passages, each under-vane passage communicating with an under-vane pocket through a connector passage, and optionally:-
each wear disk includes flow passages for communicating fluid into the under-vane pockets and under-vane passages associated with each vane slot based and the pressure of the under-vane pocket is dependent on an angular position of the rotor.
19. A multi-discharge hydraulic vane pump as recited in Claim 17, wherein at least one of a) and b):-
a) the pressurized fluid in the rotor under-vane pocket whilst positioned in the inlet are segment is about equal to pump inlet pressure;
b) the pressurized fluid in the rotor under-vane pocket whilst positioned in the discharge arc segment is about equal to pump discharge pressure.
20. A multi-discharge hydraulic vane pump as recited in Claim 15, further comprising a fluid metering system for extracting fluid flow from the discharge ares of the four cam segments.
21. A multi-discharge hydraulic vane pump as recited in Claim 20, wherein at least one of a) and b):-
a) the fluid metering system has a first operating condition in which fluid is extracted from the discharge arcs of all four cam segments and combined for delivery to a source of fluid demand;
b) the fluid metering system has a second operating condition wherein fluid is extracted from a first pair of diametrically opposed discharge ares for delivery to a source of fluid demand and fluid from a second pair of diametrically opposed discharge arcs bypasses the source of fluid demand and returns to the pumping chamber.
22. A hydraulic vane pump, comprising:
a) a pump body including an interior pumping chamber and defining an inlet port for allowing fluid to be provided to the interior pumping chamber and at least one discharge port for allowing pressurized fluid to be discharged from the interior pumping chamber;
b) a cam ring disposed within the interior pumping chamber and defining a continuous peripheral cam surface, the cam ring also defining a plurality of inlet chambers and discharge chambers, the inlet chambers being arranged and configured to receive fluid from the inlet port and to distribute the fluid to the interior pumping chamber, the discharge chambers communicating with the interior pumping chamber and are arranged and configured to facilitate the discharge of pressurized fluid from the interior pumping chamber;
c) a rotor mounted for axial rotation within the interior pumping chamber and defining a pump axis;
d) a plurality of circumferentially spaced apart radially extending vanes mounted for radial movement within slots formed in the rotor, the plurality of vanes defining an equal number of circumferentially spaced apart volume chambers which extend between an outer periphery of the rotor and the cam surface for carrying pressurized fluid, wherein each vane slot has an under-vane pocket for receiving pressurized fluid based on an angular position of the rotor, and
e) axially opposed first and second wear disks disposed within the interior pumping chamber, the first wear disk having an outer periphery which is positioned radially inward of the cam surface, and is axially biased towards a first end surface of the rotor so as to provide for thermal expansion of the rotor and vanes and the second wear disk being positioned adjacent to a second end surface of the rotor.
23. The hydraulic vane pump as recited in Claim 22, wherein each wear disk includes flow passages for feeding fluid into the under-vane pockets associated

with each vane slot and the pressure of the under-vane pocket is dependent on an angular position of the rotor.

5

10

15

20

25

30

35

40

45

50

55

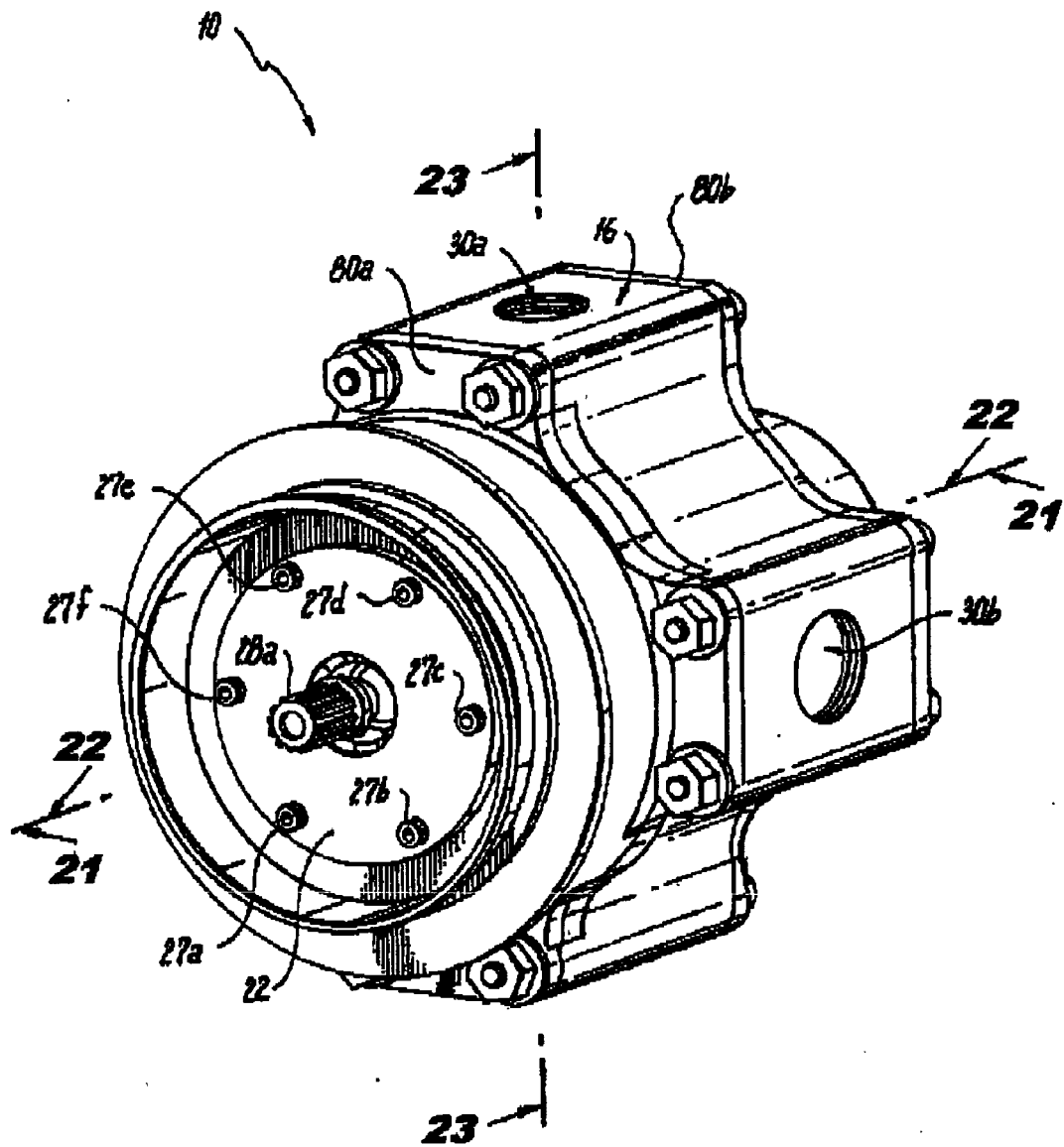


Fig. 1

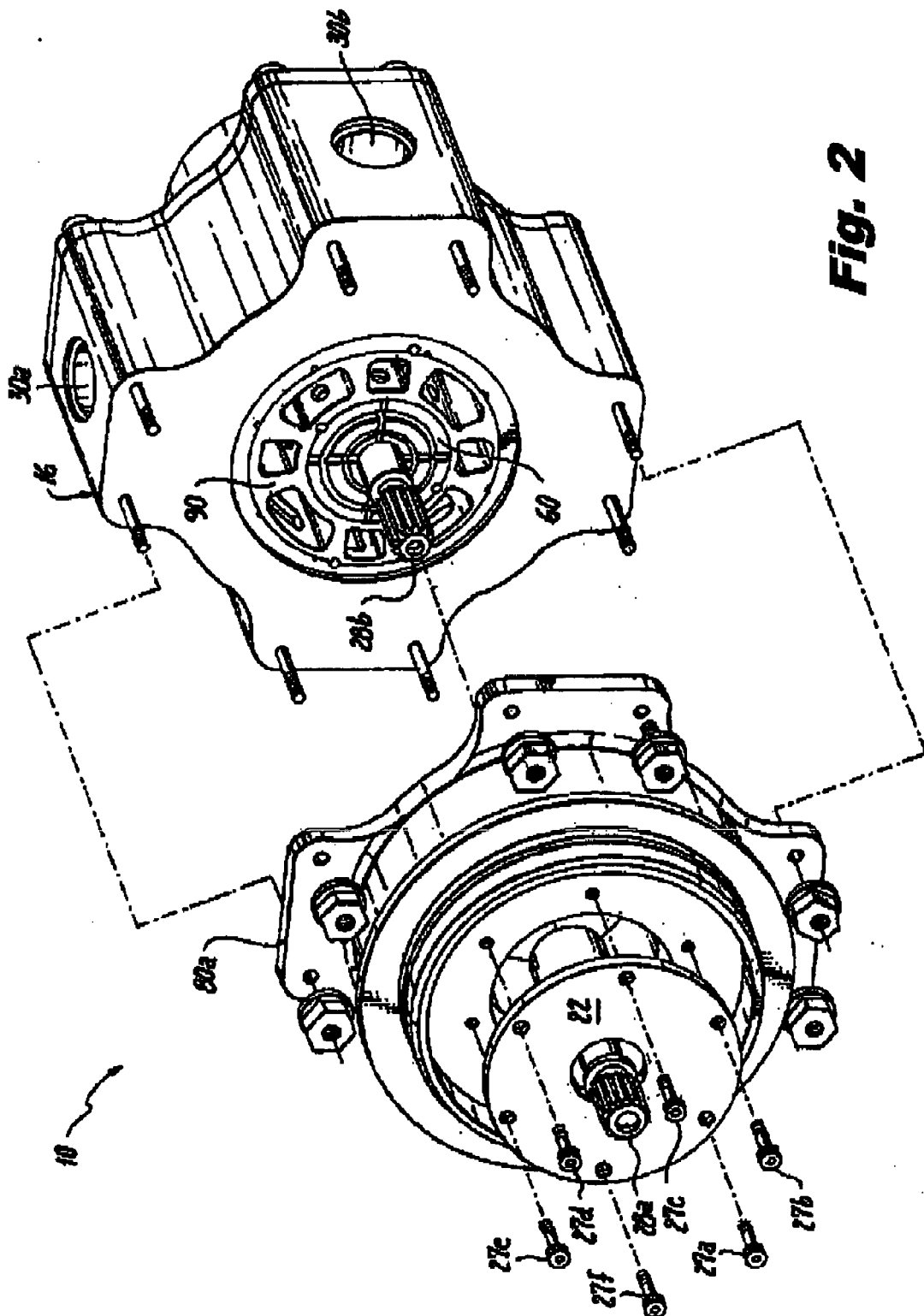


Fig. 2

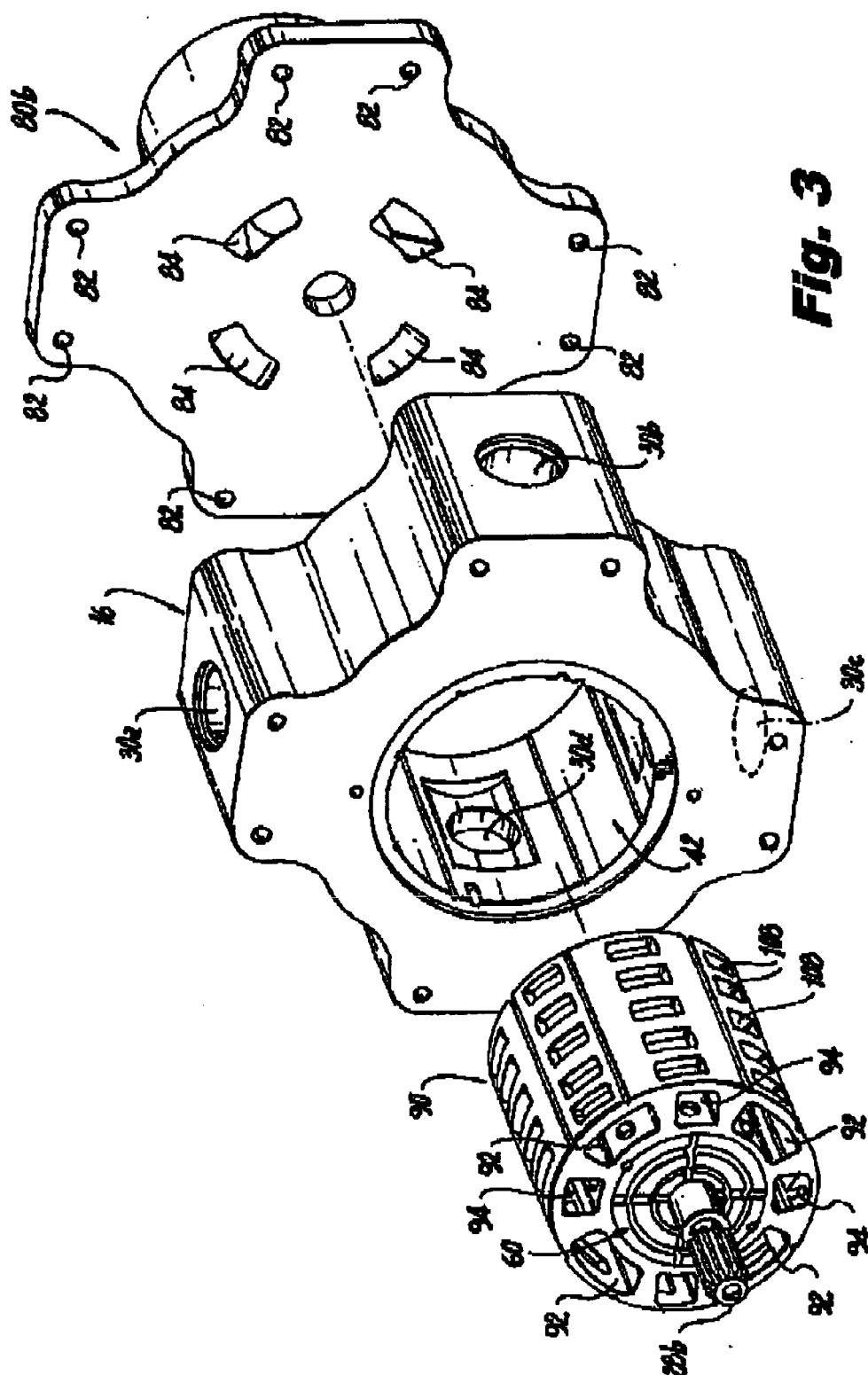


Fig. 3

Fig. 4

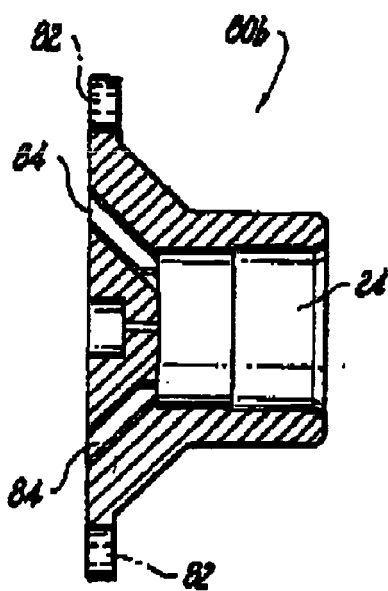
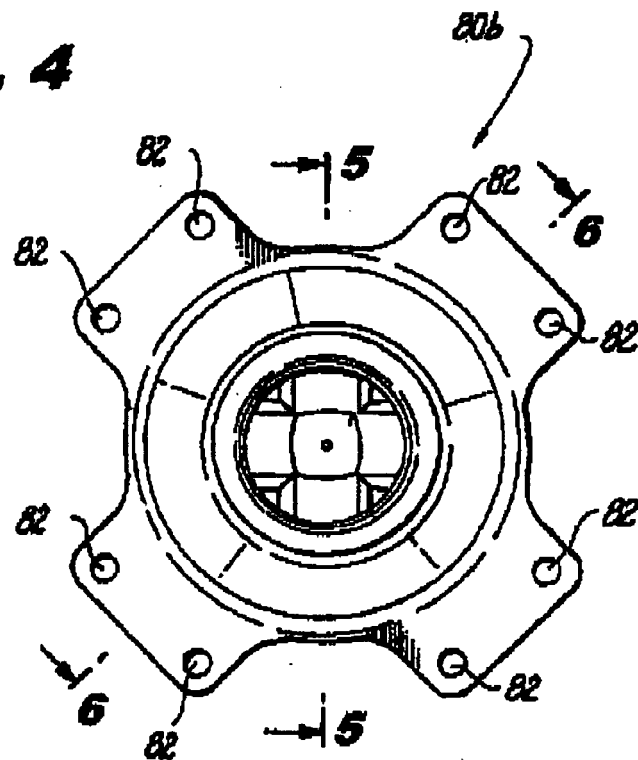


Fig. 5

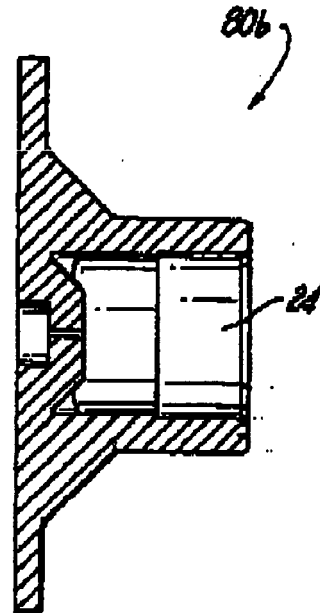


Fig. 6

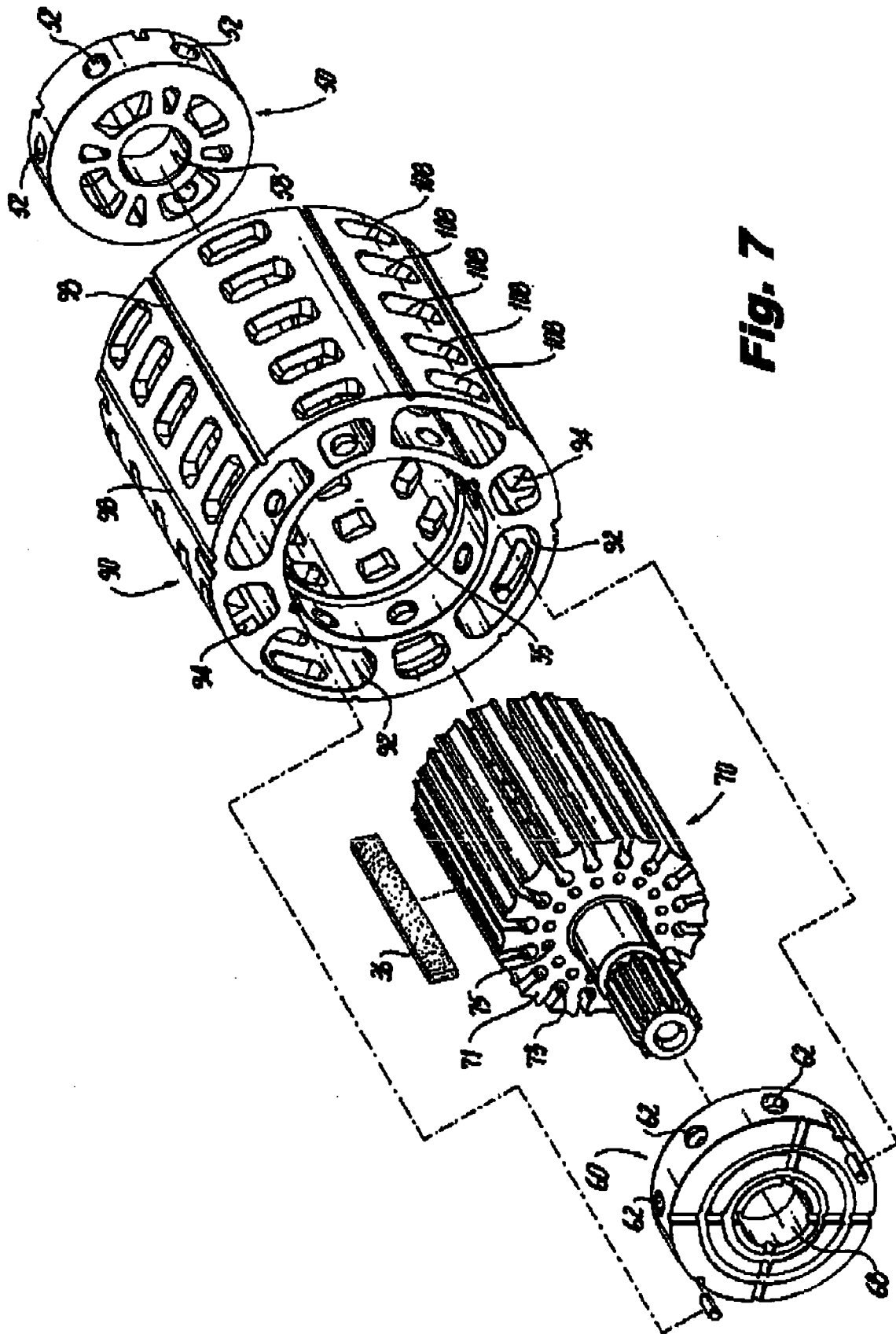


Fig. 7

Fig. 8

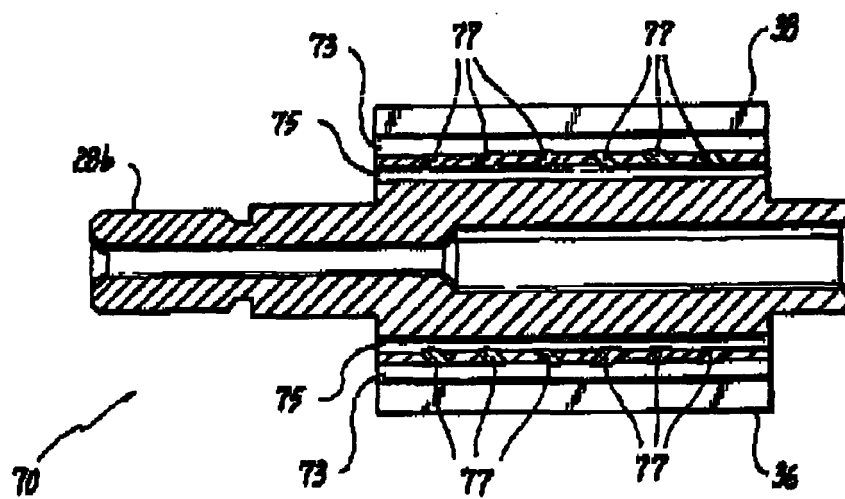
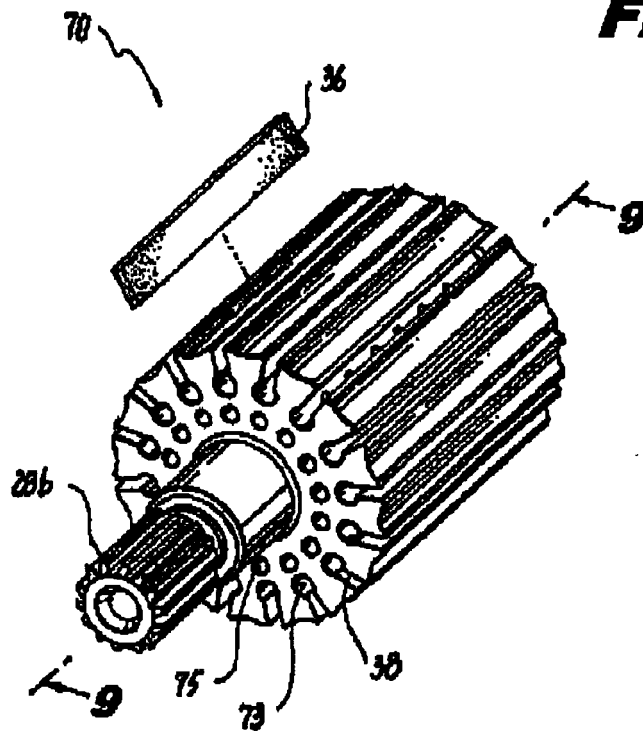


Fig. 9

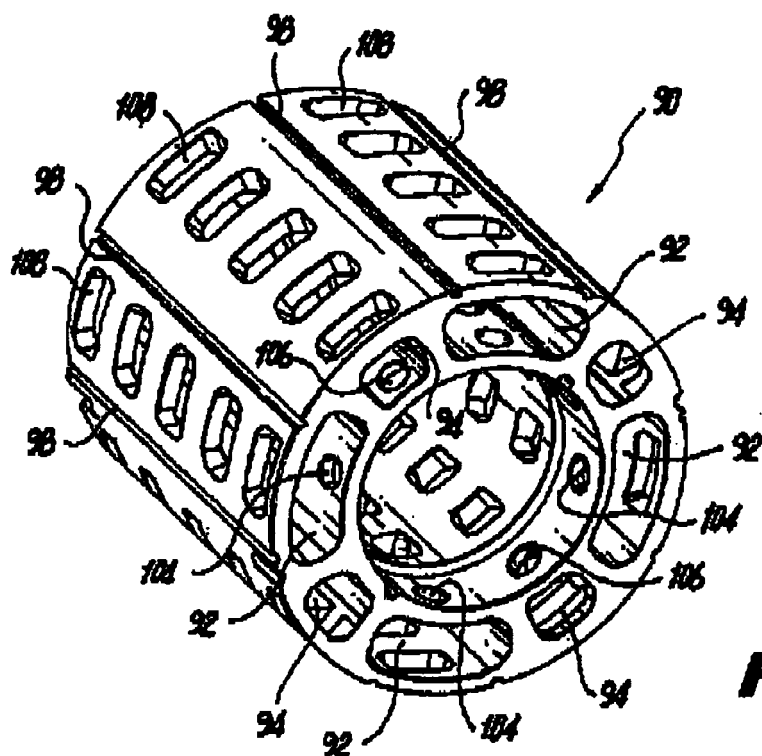


Fig. 10

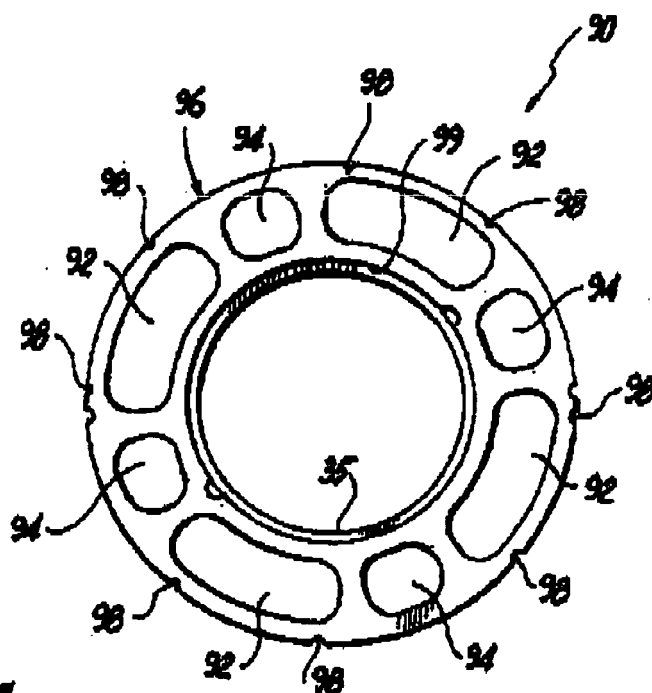


Fig. 11

Fig. 12

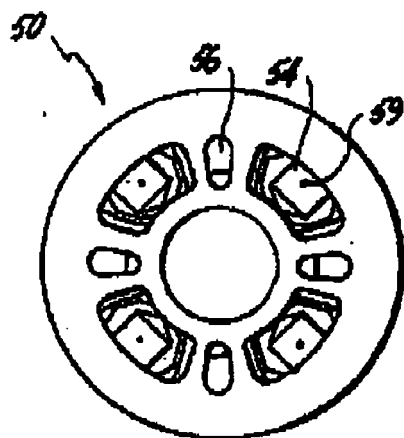
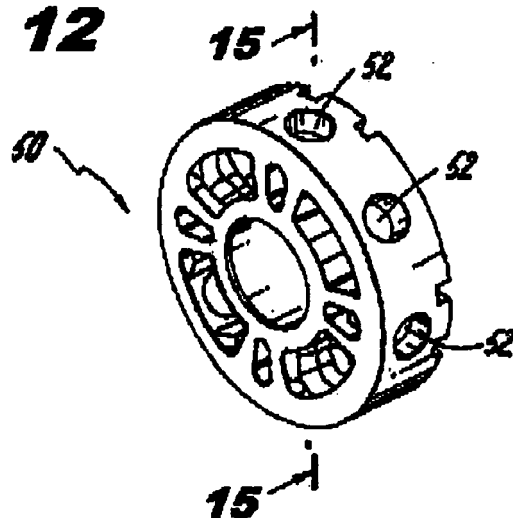


Fig. 13

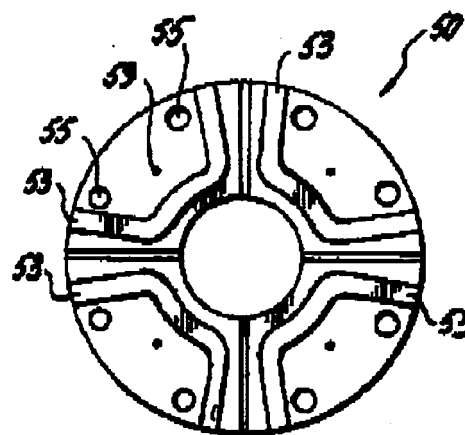


Fig. 14

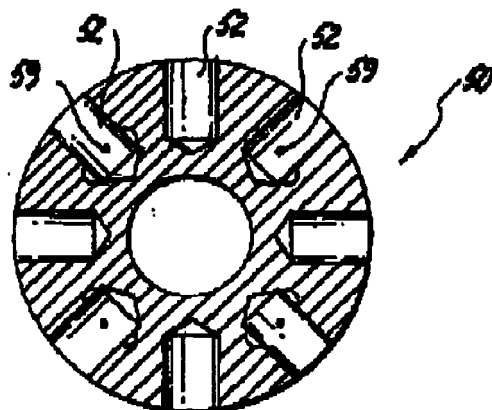


Fig. 15

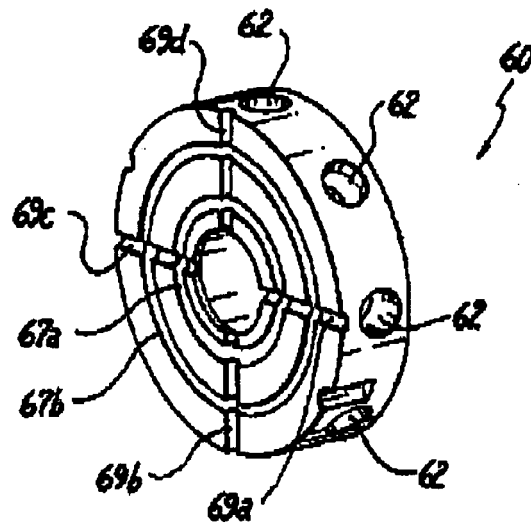


Fig. 16

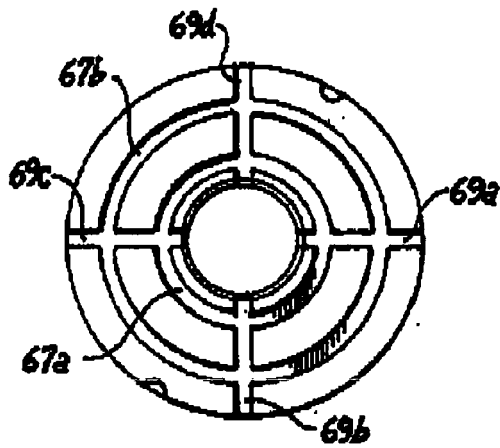


Fig. 17

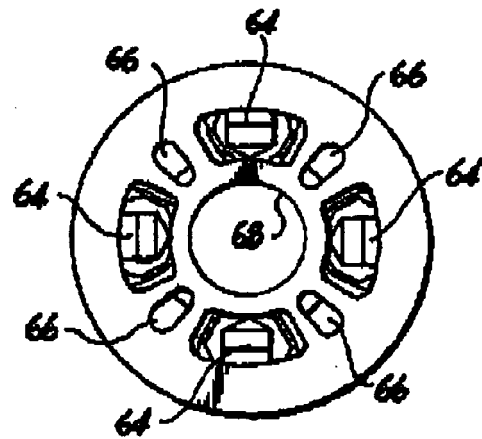
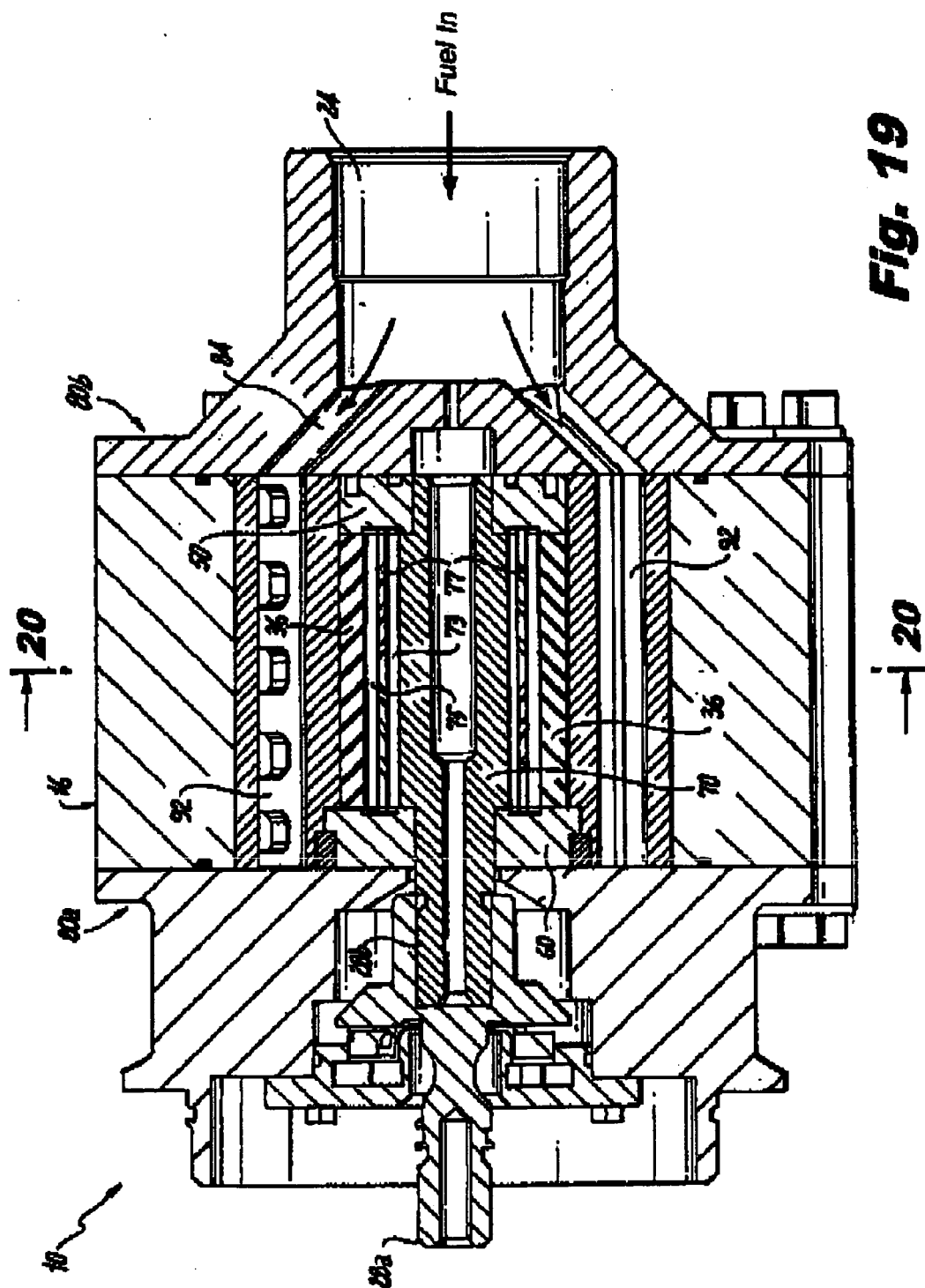


Fig. 18



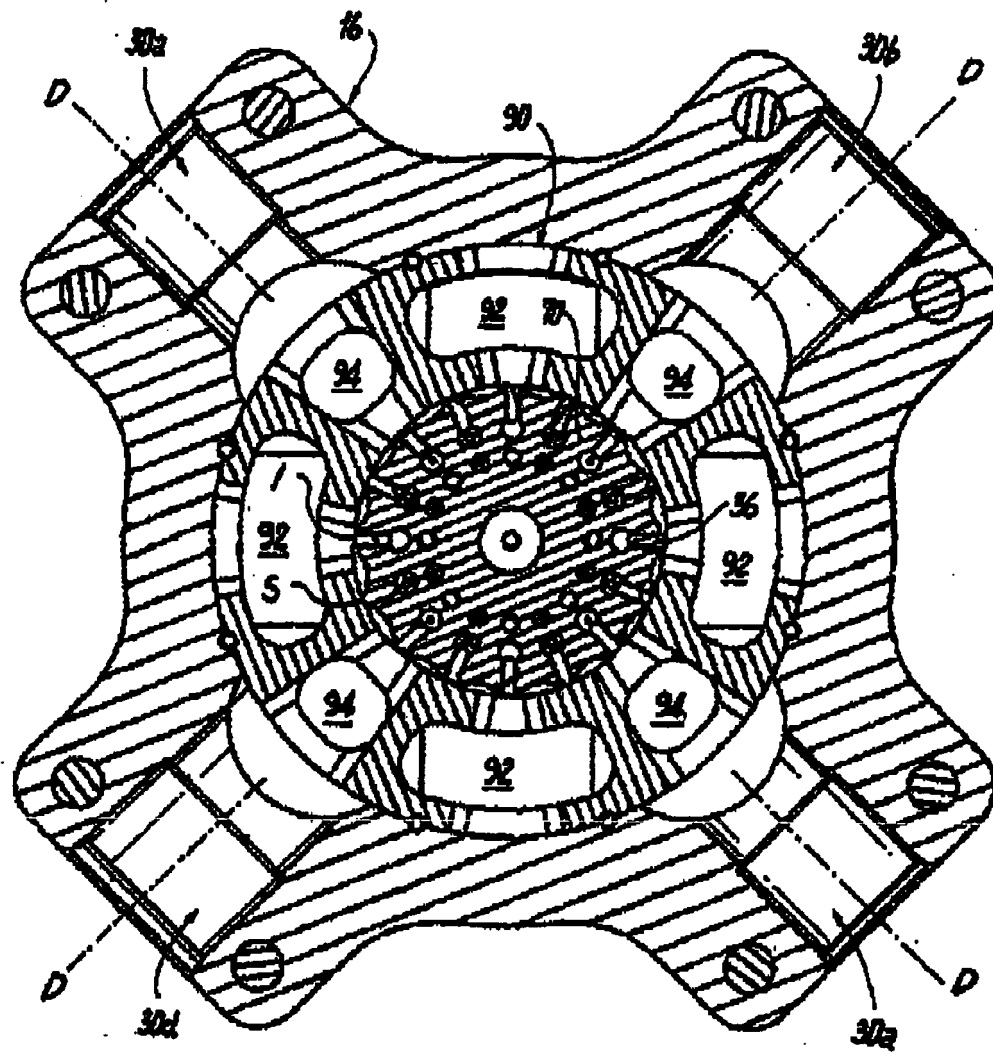
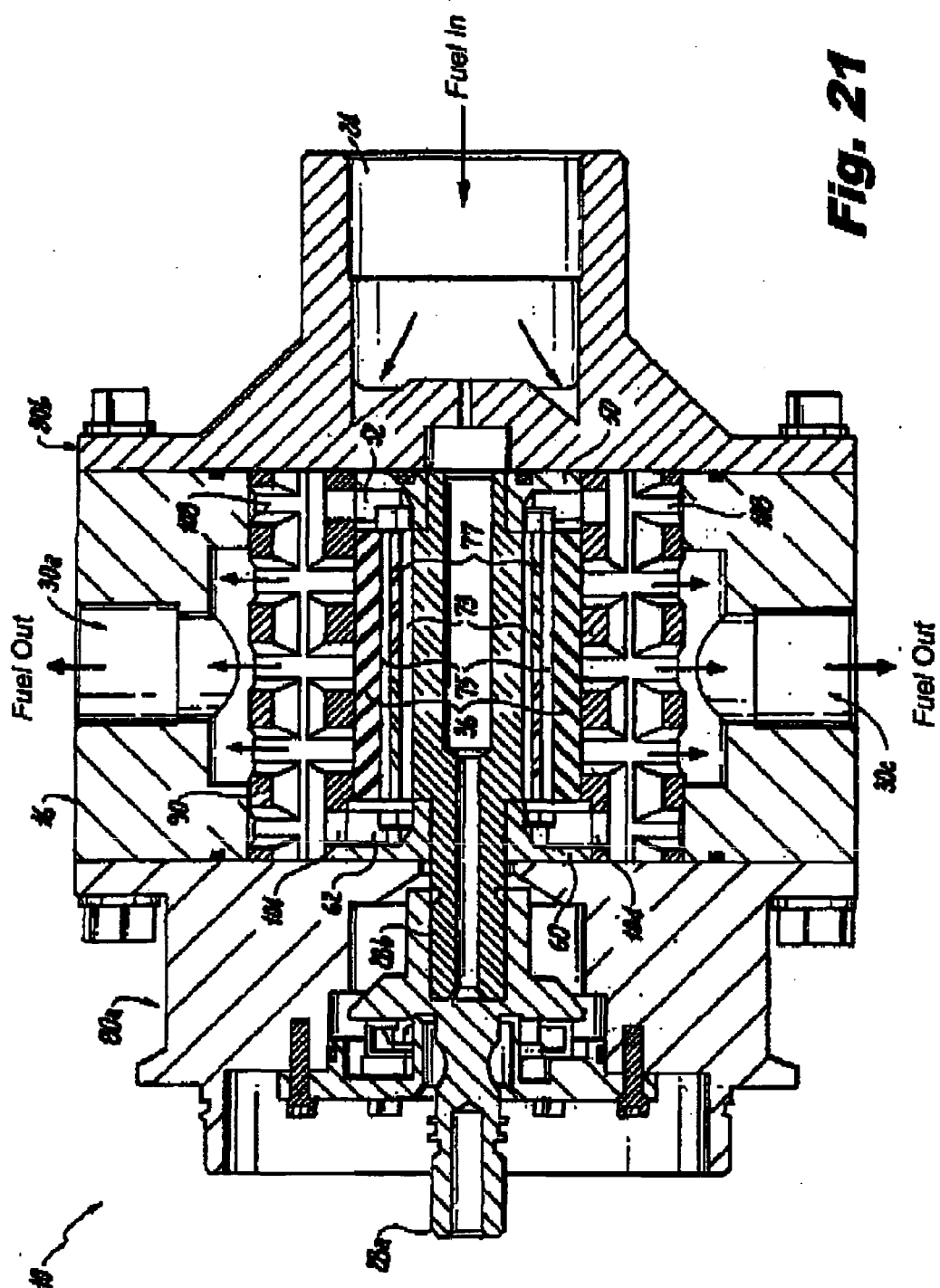


Fig. 20



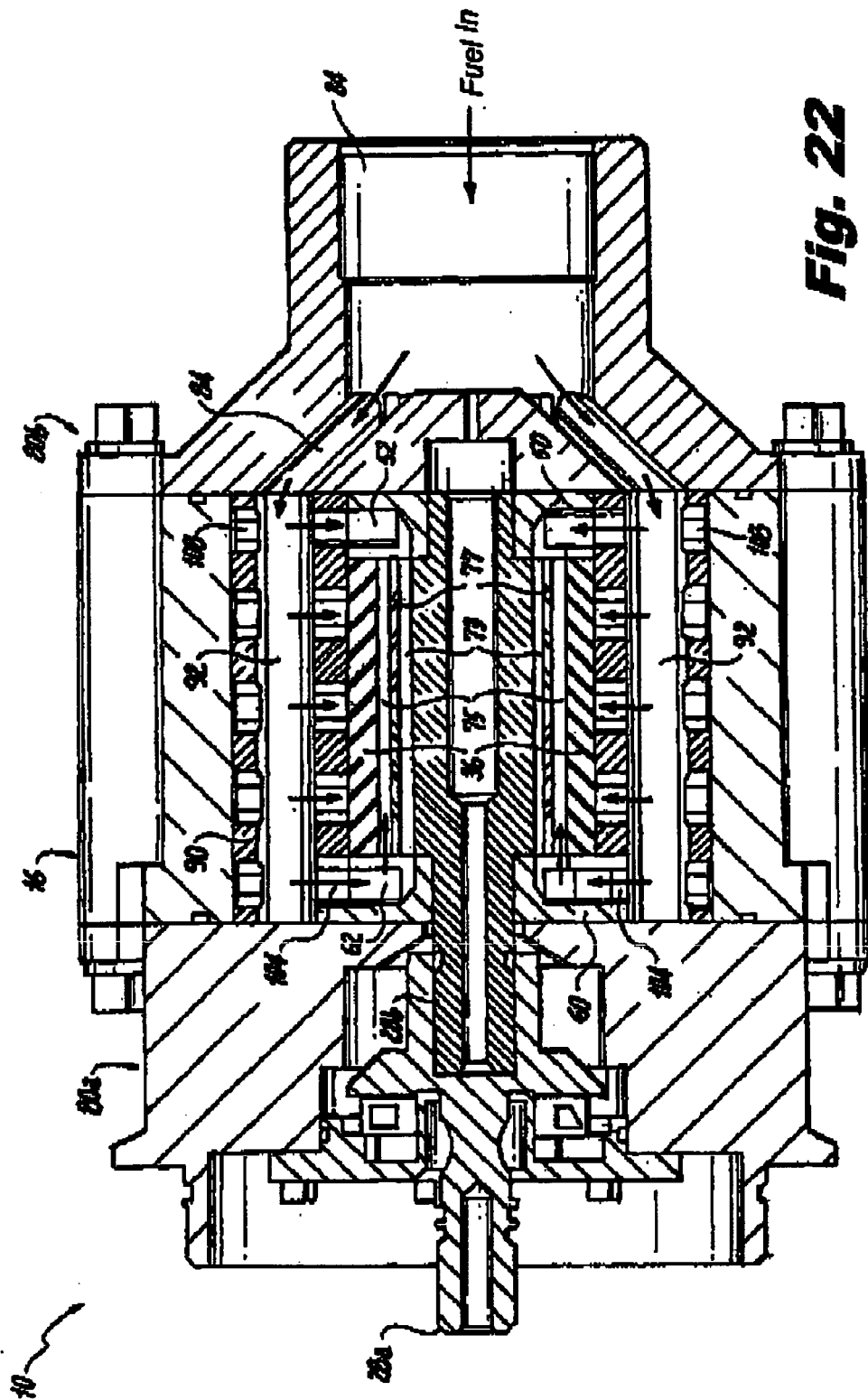


Fig. 22

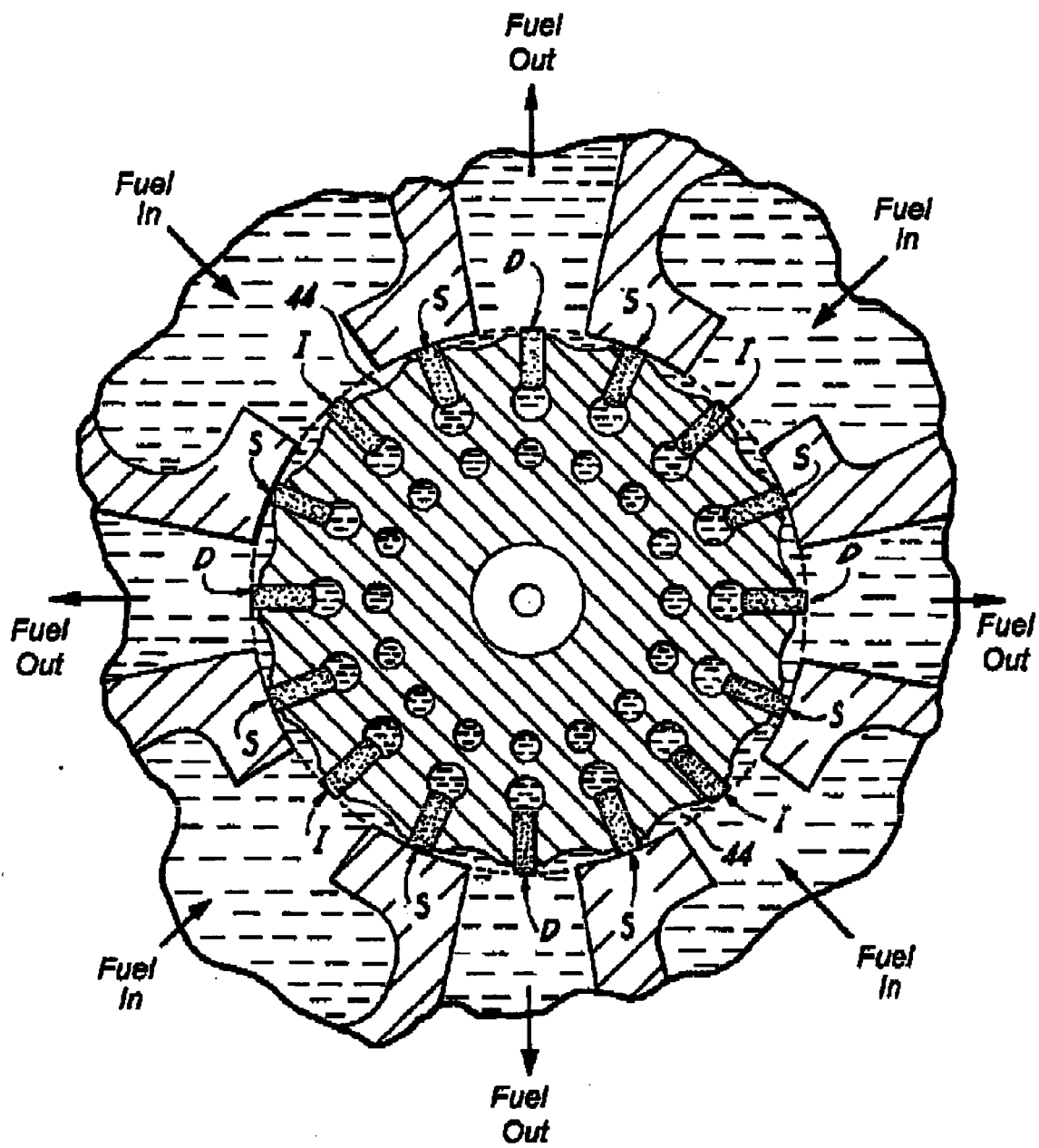


Fig. 23

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 4274817 A, Sakamaki [0003]
- US 5064362 A, Hansen. A [0003]
- US 20100316507 A [0006] [0007] [0098]