(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 528 077 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.03.2025 Bulletin 2025/13

(21) Application number: **24201793.7**

(22) Date of filing: **20.09.2024**

(51) International Patent Classification (IPC):
F01C 21/08 *(2006.01)* ***F01C 21/10*** *(2006.01)*
F04C 2/344 *(2006.01)* ***F04C 15/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04C 2/3446; F01C 21/0863; F01C 21/108;
F04C 15/0042

(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 ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **22.09.2023 US 202318371770**

(71) Applicant: **Hamilton Sundstrand Corporation**
Charlotte, NC 28217-4578 (US)

(72) Inventors:
- **GOY, Edward W.**
  Crystal Lake, 60014 (US)
- **KASSEL, John M.**
  Huntley, 60142, (US)

(74) Representative: **Dehns**
10 Old Bailey
London EC4M 7NG (GB)

(54) VANE PUMP WITH KIDNEY PORT CONFIGURATIONS IN PORT PLATES FOR BALANCED VANES

(57) A vane pump system includes a kidney port plate engaged at an axial end of a rotor and liner. The port kidney plate includes an over vane inlet port configured to be circumferentially aligned with an inlet arc segment of a circumferential cam surface of the liner for ingress of fluid to a plurality of vanes, and an over vane discharge port configured to be circumferentially aligned with a discharge arc segment of the circumferential cam surface for discharging pressurized fluid from the plurality of vanes. The kidney port plate includes at least six kidney ports radially inward from the over vane inlet port and the over vane discharge port. The kidney ports are circumferentially spaced apart from one another. The kidney ports are configured to be radially aligned with vane slots of the rotor for pressure balancing across over vane and under vane ends of the plurality of vanes.

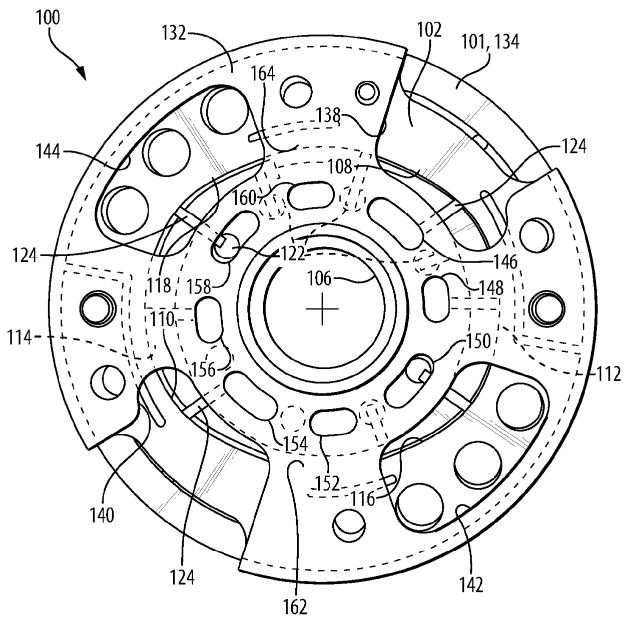

Fig. 3

EP 4 528 077 A1

Description

FIELD OF INVENTION

[0001] The present disclosure relates to vane pumps, and more particularly to a vane pump employing radially pressure balanced vanes with improved durability features.

BACKGROUND

[0002] Traditionally, vane pumps used straight vanes such as those described in U.S. Patent No. 6,634,865. To improve pressure balancing on the vanes in the radial direction, the geometry of the vanes can be altered from the traditional straight vanes, e.g., as shown and described in U.S. patent No. 7,637,724. Each of these Patents is incorporated by reference herein in its entirety.

[0003] The conventional techniques have been considered satisfactory for their intended purpose. However, there is an ever present need for improved systems and methods for pressure balancing the vanes in vane pumps, e.g. to improve durability and/or relax material property requirements. This disclosure provides a solution for this need.

SUMMARY

[0004] A vane pump system includes a kidney port plate configured to be engaged at an axial end of a rotor and of a liner. The port plate is configured to be mounted stationary relative to the liner. The port kidney plate includes an over vane inlet port configured to be circumferentially aligned with an inlet arc segment of a circumferential cam surface of the liner for ingress of fluid to a plurality of vanes. The kidney port plate includes an over vane discharge port configured to be circumferentially aligned with a discharge arc segment of the circumferential cam surface for discharging pressurized fluid from the plurality of vanes. The kidney port plate includes at least six kidney ports radially inward from the over vane inlet port and the over vane discharge port. The kidney ports are circumferentially spaced apart from one another. The kidney ports are configured to be radially aligned with vane slots of the rotor for pressure balancing across over vane and under vane ends of the plurality of vanes.

[0005] The plurality of vanes can be made of tool steel. There can be eight kidney ports including a first inlet kidney port and the following seven kidney ports. A first pressure regulated kidney port can be circumferentially adjacent to the first inlet kidney port. A first discharge kidney port can be circumferentially adjacent to the first pressure regulated kidney port. A second pressure regulated kidney port can be circumferentially adjacent to the first discharge kidney port. A second inlet kidney port can be circumferentially adjacent to the second pressure regulated kidney port. A third pressure regulated kidney port can be circumferentially adjacent to the second inlet kidney port. A second discharge kidney port can be circumferentially adjacent to the third pressure regulated kidney port. A fourth pressure regulated kidney port can be circumferentially adjacent to the second discharge kidney port. The first inlet kidney port can be circumferentially adjacent to the fourth pressure regulated kidney port.

[0006] The can be six kidney ports including a first inlet kidney port and a first discharge kidney port circumferentially adjacent to the first inlet kidney port. A first regulated pressure kidney port can be circumferentially adjacent to the first discharge kidney port. A second inlet kidney port can be circumferentially adjacent to the first regulated pressure kidney port. A second discharge kidney port can be circumferentially adjacent to the second inlet pressure kidney port. A second regulated pressure kidney port can be circumferentially adjacent to the second discharge kidney port. The first inlet kidney port can be circumferentially adjacent to the second regulated pressure kidney port. A pressure regulating valve (PRV) in a pressure balancing passage can be configured so pressure from discharge can be ported to the first and second regulated pressure kidney ports, wherein the PRV is configured to reduce pressure from the discharge to an intermediate pressure between inlet pressure and discharge pressure of the rotor to balance vane loading in the first and second pump arc segments and in the first and second seal arc segments.

[0007] The liner can have a bore extending therethrough and defines the circumferential cam surface of a pumping cavity, with a rotation axis defined in an axial direction through the bore. The circumferential cam surface can include the discharge arc segment, the inlet arc segment and a pump arc segment circumferentially separating the inlet arc segment and the discharge arc segment from one another. The rotor can be mounted for rotational movement within the bore of the liner about the rotation axis. The rotor can have a central body portion which includes the vane slots. The vane slots can be a plurality of circumferentially spaced apart radially extending vane slots formed in the rotor. Each vane slot can support a corresponding one of the vanes mounted for radial movement therein. Each of the vanes can have a radially outer tip surface adapted for slideably engaging the circumferential cam surface of the pumping cavity and a radially inner portion within each vane slot.

[0008] The first pressure regulated kidney port can be circumferentially aligned with the pump arc segment. The inlet arc segment can be a first inlet arc segment. The second pressure regulated kidney port can be circumferentially aligned with a seal arc segment that is circumferentially between the discharge arc segment and a second inlet arc segment diametrically opposed to the first inlet arc segment. The third pressure regulated kidney port can be circumferentially aligned with a second pump arc that is diametrically opposed to the first pump arc segment. The fourth pressure regulated kidney port can be circumferentially aligned with a second seal arc segment that is diametrically opposed to the first seal arc segment. The first discharge kidney port can be circumferentially aligned with the discharge arc segment. The second discharge kidney port can be circumferentially aligned with a second discharge arc segment that is diametrically opposed to the first discharge arc segment. The first inlet kidney port can be circumferentially aligned with the inlet arc segment. The second inlet kidney port can be circumferentially aligned with a second inlet arc segment that is diametrically opposed to the first inlet arc segment.

[0009] A pressure loaded port plate can be mounted to an axial end of the liner opposite across the liner from the kidney port plate. The pressure loaded port plate can be fixed relative to the liner. A shouldered end cap can be mounted to the pressure loaded port plate and to the liner, with the shouldered end cap radially outboard of the liner, and with the pressure loaded port plate axially between the shouldered end cap and the liner. A discharge end cap can be mounted to the kidney port plate, with the kidney port plate axially between the discharge end cap and the liner.

[0010] A first fluid communication passage can be included configured so over vane pressure can be ported to the first and second discharge kidney ports through at least one of the rotor, the kidney port plate, the shouldered end cap, or the discharge end cap. A second fluid communication passage can be included, configured so vane pump inlet pressure can be ported to the first and second inlet kidney ports through at least one of the rotor, the kidney port plate, the shouldered end cap, or the discharge end cap.

[0011] A pressure regulating valve (PRV) can be included in a pressure balancing passage configured so pressure from discharge can be ported to the four pressure regulated kidney ports. The PRV can be configured to reduce pressure from the discharge to an intermediate pressure between inlet pressure and discharge pressure of the rotor to balance vane loading in the first and second pump arc segments and in the first and second seal arc segments. The pressure balancing passage can be configured so pressure can be ported to the four pressure regulated kidney ports through at least one of the discharge end cap and the shouldered end cap. A pressure regulating valve (PRV) can be included in a pressure balancing passage configured so pressure from discharge can be ported to first and second regulated pressure kidney ports, wherein the PRV is configured to reduce pressure from the discharge to an intermediate pressure between inlet pressure and discharge pressure of the rotor to balance vane loading in the first and second pump arc segments and in the first and second seal arc segments.

[0012] These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description of the preferred embodiments taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

Fig. 1 is a schematic axial cross-sectional end view of an embodiment of portion of a vane pump system constructed in accordance with the present disclosure, showing the rotor, liner, and the vanes interacting with the rotor and the camming surface of the liner;

Fig. 2 is a schematic exploded perspective view of the system of Fig. 1, showing the kidney port plate, the pressure loaded plate, and the end caps;

Fig. 3 is a schematic axial end view of a portion of the system of Fig. 1, showing the alignment of the kidney ports with the arcs of the camming surface of the liner;

Fig. 4 is a schematic view of the a portion of the system of Fig. 1, oriented as in Fig. 1, schematically indicating over vane and under vane pressures loading one of the vanes of Fig. 1, e.g. the upper most vane as oriented in Fig. 1;

Figs. 6-7 are schematic views of pressure passages in the system of Fig. 1 for the discharge kidney ports, for the inlet kidney ports, and for the pressure regulated kidney ports of the kidney port plate of Fig. 3, respectively; and

Fig. 8 is a schematic axial end view of a portion of the system of Fig. 3, showing a configuration with six kidney ports.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject disclosure. For purposes of explanation and illustration, and not limitation, a partial view of an embodiment of a system in accordance with the disclosure is shown in Fig. 1 and is designated generally by reference character 100. Other embodiments of systems in accordance with the disclosure, or aspects thereof, are provided in Figs. 2-8, as will be described. The systems and methods described herein can be used to pressure balance over vane and under vane pressures of vanes in vane pumps, which can make possible the use of fracture tough materials for the vanes.

[0015] The vane pump system 100 includes a liner 102 that has a bore extending therethrough that defines the circumferential cam surface 104 of a pumping cavity. A rotation axis A is defined in an axial direction through the bore. The circumferential cam surface 104 includes two sets of functional pumping cam arcs to balance the rotor 106 arc segment. There are two diametrically opposed inlet arc segments 108, 110 of the cam surface 104. Downstream of each (with respect to the flow of fluid from the inlets 101) is a respective pump arc segment 112, 114 of the cam surface 104 circumferentially separating each of the inlet arc segments 108, 110 from a respective discharge arc segment 116, 118 of the cam surface 104 from one another. There are two diametrically opposed seal arc segments 162, 164 of the cam surface 104, circumferentially separating first set of pumping cam arcs 104, 112, 106 from the second set of pumping cam arcs 110, 114, 118.

[0016] The cylindrical rotor 106 is mounted for rotational movement within the bore of the liner 102 about the rotation axis A. The rotor 106 has a central body portion 120 which includes the plurality of circumferentially spaced apart radially extending vane slots 122. Each vane slot 122 supports a corresponding one of the vanes 124 mounted for radial movement therein relative to the rotation axis A as the outer (or over vane) tips 126 (labeled in Fig. 4) of the vanes 124 slidingly engage and follow the cam surface 104. Each of the vanes 124 has a radially inner (or under vane) portion 128 (labeled in Fig. 4), relative to the rotation axis A. The radially inner portion 128 of each vane 124 is seated slidingly within its respective vane slot 122.

[0017] With reference now to Fig. 2, a pressure loaded port plate 130 is mounted to an axial end of the liner 102 opposite across the liner from a kidney port plate 132, which is mounted to the other end of the liner 102. The port plates 130, 132 are fixed relative to the liner 102. A shouldered end cap 134 is mounted to the pressure loaded port plate 130 and to the liner 102, with the shouldered end cap 134 radially outboard of the liner 102, and with the pressure loaded port plate 130 axially between the shouldered end cap 134 and the liner 102. The inlets for the vane pump system pass through the shouldered end cap 134 where indicated in Fig. 2 and pressure plate port 130 to the inlet 101 positions indicated in Fig. 1. A discharge end cap 136 is mounted to the kidney port plate 132, with the kidney port plate 132 axially between the discharge end cap 136 and the liner 102. The discharge end plate 136 includes the discharge outlets 103 of the pump system 100.

[0018] With reference now to Fig. 3, the kidney port plate 132 includes an diametrically opposed pair of over vane inlet ports 138, 140 circumferentially aligned (relative to the rotation axis A) with their respective inlet arc segment 108, 110 for ingress of fluid to a plurality of vanes 124. The kidney port plate 132 includes a pair of diametrically opposed over vane discharge ports 142, 144 circumferentially aligned (relative to the rotation axis A) with their respective discharge arc segments 116, 118 for discharging pressurized fluid from the plurality of vanes 124. The kidney port plate 132 includes kidney ports 146, 148, 150, 152, 154, 156, 158, 160 radially inward with respect to the rotation axis A relative to the over vane inlet ports 138, 140 and the over vane discharge ports 142, 144. The kidney ports 146, 148, 150, 152, 154, 156, 158, 160 are circumferentially spaced apart from one another relative to the rotation axis A. The kidney ports 146, 148, 150, 152, 154, 156, 158, 160 are radially aligned, i.e. on the same radial distance from the rotation axis A, with vane slots 122 of the rotor 102 for pressure balancing across the over vane and under vane ends 126, 128 of the plurality of vanes 124.

[0019] A first pressure regulated or pressure regulated kidney port 148 is circumferentially adjacent to the first inlet kidney port 146. A first discharge kidney port 150 is circumferentially adjacent to the first pressure regulated kidney port 148. A second pressure regulated kidney port 152 is circumferentially adjacent to the first discharge kidney port 150. A second inlet kidney port 154 is circumferentially adjacent to the second pressure regulated kidney port 152. A third pressure regulated kidney port 156 is circumferentially adjacent to the second inlet kidney port 154. A second discharge kidney port 158 is circumferentially adjacent to the third pressure regulated kidney port 156. A fourth pressure regulated kidney port 160 is circumferentially adjacent to the second discharge kidney port 158. The first inlet kidney port 146 is circumferentially adjacent to the fourth pressure regulated kidney port 160. Optionally two of the kidney ports can be omitted, as discussed below with respect to Fig. 8.

[0020] With ongoing reference to Fig. 3, where circumferential references continue to be with respect to the rotation axis A, the first pressure regulated kidney port 148 is circumferentially aligned with the first pump arc segment 112. The second pressure regulated kidney port 152 is circumferentially aligned with the seal arc segment 162. The third pressure regulated kidney port 156 is circumferentially aligned with a second pump arc 114. The fourth pressure regulated kidney port 160 is circumferentially aligned with a second seal arc segment 164. The first discharge kidney port 150 is circumferentially aligned with the discharge arc segment 116. The second discharge kidney port 158 is circumferentially aligned with the second discharge arc segment 118. The first inlet kidney port 146 is circumferentially aligned with the inlet arc segment 108. The second inlet kidney port 154 is circumferentially aligned with the second inlet arc segment 110.

[0021] With reference now to Figs. 5 and 6, a first fluid communication passage 166 is included configured so over vane pressure from the discharge ports 142, 144 can be ported to the first and second discharge kidney ports 150, 158 through at least one of the rotor 102, the pressure loaded port plate 130, the kidney port plate 132, the shouldered end cap 134, and/or the discharge end cap 136. A second fluid communication passage 168 is included configured so vane pump inlet pressure can be ported to the first and second inlet kidney ports 146, 154 through at least one of the rotor 102, the pressure loaded port plate 130, the kidney port plate 132, the shouldered end cap 134, and/or the discharge end cap 136.

[0022] With reference now to Fig. 7, a pressure regulating valve (PRV) 170 is included in a pressure balancing passage 172 configured so pressure from the over vane or under vane discharge 142, 144, 150, 158 can be ported to the four pressure regulated kidney ports 148, 152, 156, 160. The PRV 170 is configured to reduce pressure from the discharge 142, 144, 150, 158 to an intermediate pressure between inlet pressure (at inlets 101 of Figs. 1-4) and discharge pressure of the rotor 102 (labeled in Figs. 1-4) to balance vane loading (indicated in Fig. 4) in the first and second pump arc segments and in the first and second seal arc segments 112, 114 (labeled in Fig. 1). The pressure balancing passage 172 is configured so pressure can be ported to the four pressure regulated kidney ports 148, 152, 156, 160 through at least one of the discharge end cap 136 and the shouldered end cap 134. This pressure balancing accommodates more fracture tough materials for the vanes 124 (labeled in Figs. 1-4) than was feasible with traditional configurations. The plurality of vanes 124 can be made of tool steel, for example.

[0023] With reference again to Figs. 1-4, the seal zones can be isolated with the kidney port plate 132. The straight vanes 124 can be ported inlet pressure, discharge pressure, or a regulated pressure of discharge - inlet pressure plus some margin to positively load the vanes into the liner 102. The PRV 170 of Fig. 7 creates pressure between inlet and discharge which is ported to the under vane cavities 122 to either match exactly the over vane net pressures or provide a slightly positive net pressure loading on the vane towards the liner 102.

[0024] With reference now to Fig. 8, a six kidney port configuration is disclosed, similar to the eight kidney port configuration of Figs. 1-3 but with two fewer pressure regulated kidney ports. In this case, the kidney port plate 132 includes first inlet kidney port 246 and a first discharge kidney port 248 circumferentially adjacent to the first inlet kidney port 246. A first regulated pressure kidney port 250 is circumferentially adjacent to the first discharge kidney port 248. A second inlet kidney port 252 is circumferentially adjacent to the first regulated pressure kidney port 250. A second discharge kidney port 254 is circumferentially adjacent to the second inlet pressure kidney port 252. A second regulated pressure kidney port 256 is circumferentially adjacent to the second discharge kidney port 254. The first inlet kidney port 246 is circumferentially adjacent to the second regulated pressure kidney port 256. Much as described above with respect to Fig. 7, a pressure regulating valve (PRV) 178 in a pressure balancing passage 172 can be configured so pressure from discharge can be ported to the first and second regulated pressure kidney ports 250, 256, wherein the PRV 178 is configured to reduce pressure from the discharge to an intermediate pressure between inlet pressure and discharge pressure of the rotor to balance vane loading in the first and second pump arc segments and in the first and second seal arc segments. Seal zones can be isolated with a six kidney port plate 132. Straight vanes can be ported inlet pressure, discharge pressure, or a regulated pressure of discharge-inlet pressure plus some margin to positively load the vanes into the liner. Vane loading can be controlled with this configuration to allow more fracture tough materials such as tool steel to be utilized as the vane material. Pressure is ported to the undervane discharge kidneys 248, 254 via porting in one or multiple of the rotor, the port plate, or the end caps. Pressure is ported to the pressure regulated kidney ports 250, 256 through the end caps. Pressure is firs ported from overvane or undervane discharge to a PRV 172 and then to the pressure regulated kidney ports 250, 256 to provide undervane pressures that help balance the vane loading in those locations.

[0025] System and methods as disclosed herein provide potential benefits including the following. The low loading achieved by the above system allows for the use of fracture tough vanes even with straight vane geometries. The methods and systems of the present disclosure, as described above and shown in the drawings, provide for pressure balancing over vane and under vane pressures of vanes in vane pumps, which can make possible use of fracture tough materials for the vanes. While the apparatus and methods of the subject disclosure have been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the scope of the subject disclosure.

Claims

1. A vane pump system comprising:
a kidney port plate configured to be engaged at an axial end of a rotor and of a liner, wherein the port plate is configured to be mounted stationary relative to the liner, wherein the kidney port plate includes:

an over vane inlet port configured to be circumferentially aligned with an inlet arc segment of a circumferential cam surface of the liner for ingress of fluid to a plurality of vanes;
an over vane discharge port configured to be circumferentially aligned with a discharge arc segment of the circumferential cam surface for discharging pressurized fluid from the plurality of vanes; and
at least six kidney ports radially inward from the over vane inlet port and the over vane discharge port, wherein the kidney ports are circumferentially spaced apart from one another, and wherein the kidney ports are configured to be radially aligned with vane slots of the rotor for pressure balancing across over vane and under vane ends of the plurality of vanes.

2. The system as recited in Claim 1, wherein there are six kidney ports including:

a first inlet kidney port;
a first discharge kidney port circumferentially adjacent to the first inlet kidney port;
a first regulated pressure kidney port circumferentially adjacent to the first discharge kidney port;
a second inlet kidney port circumferentially adjacent to the first regulated pressure kidney port;
a second discharge kidney port circumferentially adjacent to the second inlet pressure kidney port; and
a second regulated pressure kidney port circumferentially adjacent to the second discharge kidney port, wherein the first inlet kidney port is circumferentially adjacent to the second regulated pressure kidney port,
optionally comprising a pressure regulating valve (PRV) in a pressure balancing passage configured so pressure from discharge can be ported to the first and second regulated pressure kidney ports, wherein the PRV is configured to reduce pressure from the discharge to an intermediate pressure between inlet pressure and discharge pressure of the rotor to balance vane loading in the first and second pump arc segments and in the first and second seal arc segments.

3. The system as recited in Claim 1, wherein there are eight kidney ports including:

a first inlet kidney port;
a first regulated pressure kidney port circumferentially adjacent to the first inlet kidney port;
a first discharge kidney port circumferentially adjacent to the first regulated pressure kidney port;
a second regulated pressure kidney port circumferentially adjacent to the first discharge kidney port;
a second inlet kidney port circumferentially adjacent to the second regulated pressure kidney port;
a third regulated pressure kidney port circumferentially adjacent to the second inlet kidney port;
a second discharge kidney port circumferentially adjacent to the third regulated pressure kidney port; and
a fourth regulated pressure kidney port circumferentially adjacent to the second discharge kidney port, wherein the first inlet kidney port is circumferentially adjacent to the fourth regulated pressure kidney port.

4. The system as recited in claim 3, further comprising:

the liner having a bore extending therethrough and defining the circumferential cam surface of a pumping cavity, with a rotation axis defined in an axial direction through the bore, the circumferential cam surface of the pumping cavity including the discharge arc segment, the inlet arc segment and a pump arc segment circumferentially separating the inlet arc segment and the discharge arc segment from one another; and
the rotor mounted for rotational movement within the bore of the liner about the rotation axis, the rotor having a central body portion which includes the vane slots, which are a plurality of circumferentially spaced apart radially extending vane slots formed in the rotor, each vane slot supporting a corresponding one of the plurality of vanes mounted for radial movement therein, each vane in the plurality of vanes having a radially outer tip surface adapted for slideably engaging the circumferential cam surface of the pumping cavity and a radially inner portion within each vane slot.

5. The system as recited in claim 4, wherein the first regulated pressure kidney port is circumferentially aligned with the pump arc segment.

6. The system as recited in claim 5, wherein the inlet arc segment is a first inlet arc segment, wherein the second regulated pressure kidney port is circumferentially aligned with a seal arc segment that is circumferentially between the discharge arc segment and a second inlet arc segment diametrically opposed to the first inlet arc segment.

7. The system as recited in claim 6, wherein the pump arc segment is a first pump arc segment, wherein the third regulated pressure kidney port is circumferentially aligned with a second pump arc diametrically opposed to the first pump arc segment.

8. The system as recited in claim 7, wherein the seal arc segment is a first seal arc segment, wherein the fourth regulated pressure kidney port is circumferentially aligned with a second seal arc segment that is diametrically opposed to the first seal arc segment, and/or
wherein the first discharge kidney port is circumferentially aligned with the discharge arc segment.

9. The system as recited in claim 8, wherein the discharge arc segment is a first discharge arc segment, wherein the second discharge kidney port is circumferentially aligned with a second discharge arc segment that is diametrically opposed to the first discharge arc segment, and/or
wherein the first inlet kidney port is circumferentially aligned with the inlet arc segment.

10. The system as recited in claim 9, wherein the inlet arc segment is a first inlet arc segment, wherein the second inlet kidney port is circumferentially aligned with a second inlet arc segment that is diametrically opposed to the first inlet arc segment.

11. The system as recited in claim 10, further comprising a pressure loaded port plate mounted to an axial end of the liner opposite across the liner from the kidney port plate, wherein the pressure loaded port plate is fixed relative to the liner.

12. The system as recited in claim 11, further comprising a shouldered end cap mounted to the pressure loaded port plate and to the liner, with the shouldered end cap radially outboard of the liner, and with the pressure loaded port plate axially between the shouldered end cap and the liner.

13. The system as recited in claim 12, further comprising a discharge end cap mounted to the kidney port plate, with the kidney port plate axially between the discharge end cap and the liner.

14. The system as recited in claim 13, wherein a first fluid communication passage is included configured so over vane pressure can be ported to the first and second discharge kidney ports through at least one of the rotor, the kidney port plate, the shouldered end cap, or the discharge end cap,
wherein optionally, a second fluid communication passage is included configured so vane pump inlet pressure can be ported to the first and second inlet kidney ports through at least one of the rotor, the kidney port plate, the shouldered end cap, or the discharge end cap.

15. The system as recited in claim 14, further comprising a pressure regulating valve (PRV) in a pressure balancing passage configured so pressure from discharge can be ported to the first, second, third, and fourth regulated pressure kidney ports, wherein the PRV is configured to reduce pressure from the discharge to an intermediate pressure between inlet pressure and discharge pressure of the rotor to balance vane loading in the first and second pump arc segments and in the first and second seal arc segments,
wherein optionally, the pressure balancing passage is configured so pressure can be ported to the first, second, third, and fourth regulated kidney ports through at least one of the discharge end cap and the shouldered end cap.

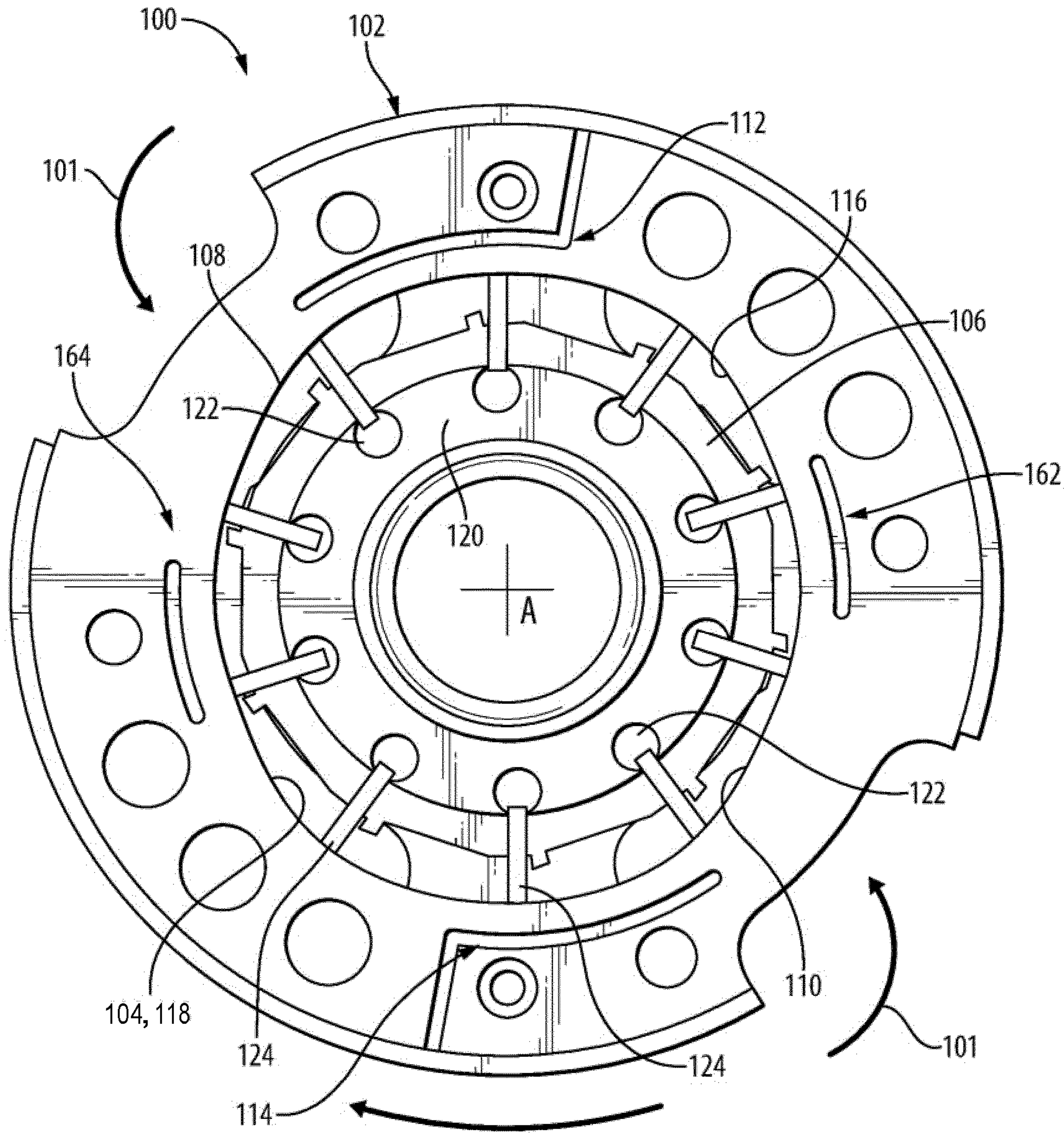
100
102
112
101
116
108
106
164
122
162
120
A
122
110
104, 118
124
124
101
114

Fig. 1

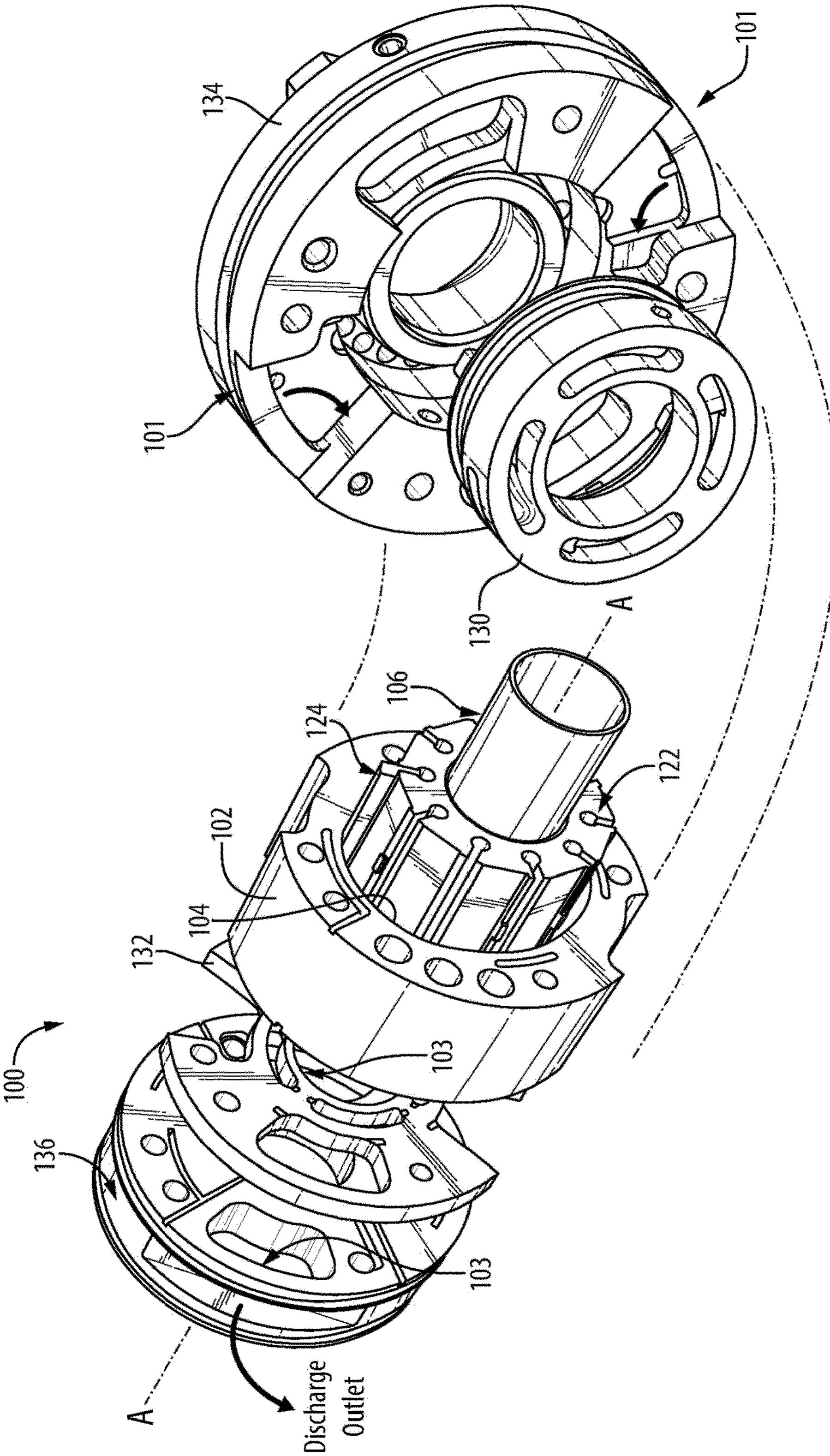
101
134
101
130
A
106
124
100
102
122
104
132
100
103
136
103
A
Discharge
Outlet

Fig. 2

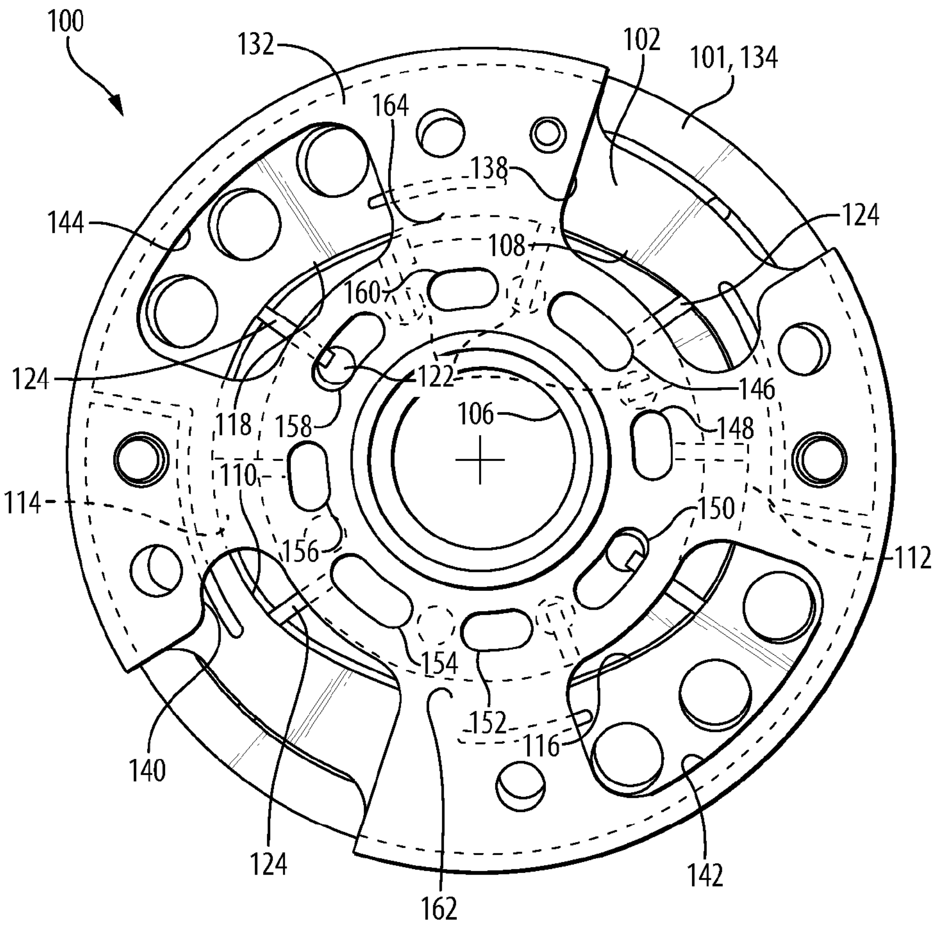
100
132
102
101, 134
164
138
144
124
108
160
124
122
146
106
118
158
148
110
114
150
112
156
154
152
116
140
124
142
162

Fig. 3

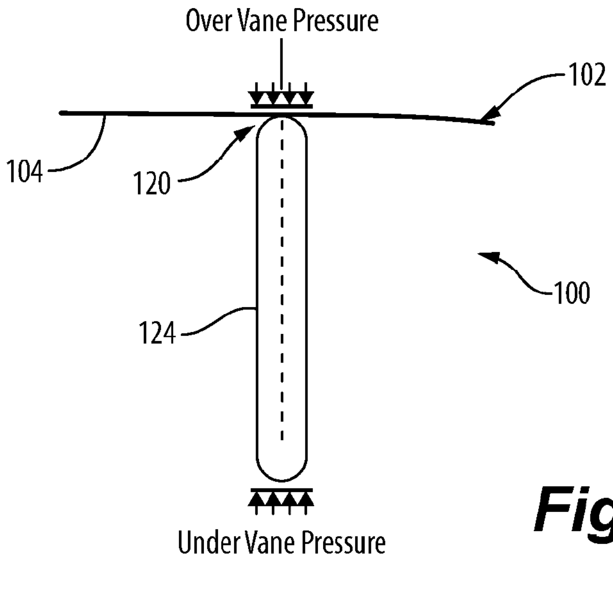
Over Vane Pressure
102
104
120
100
124
Under Vane Pressure

Fig. 4

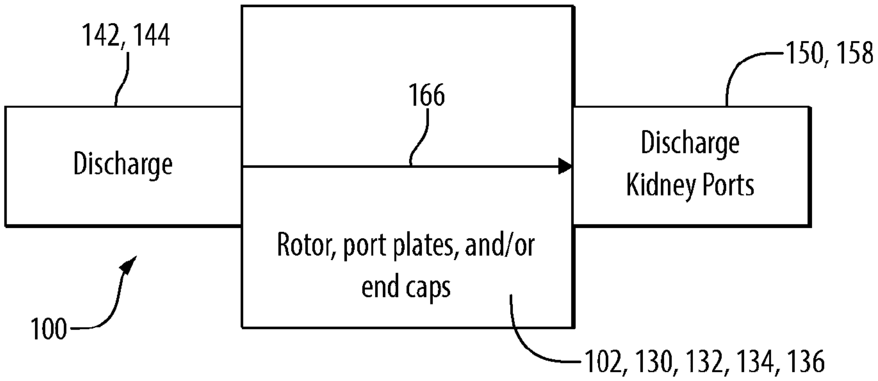

Fig. 5

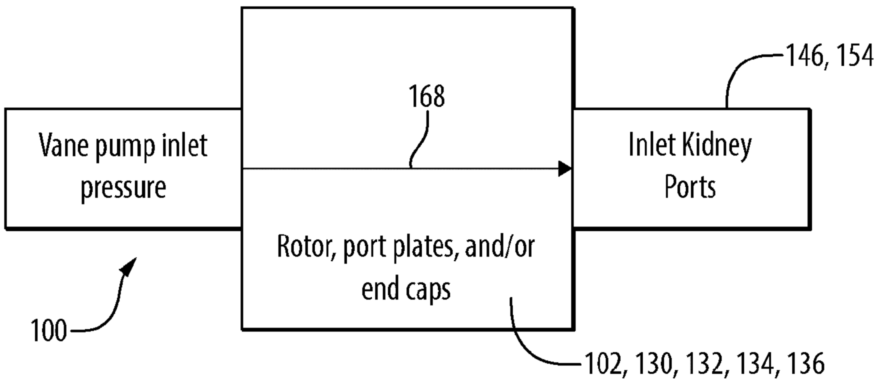

Fig. 6

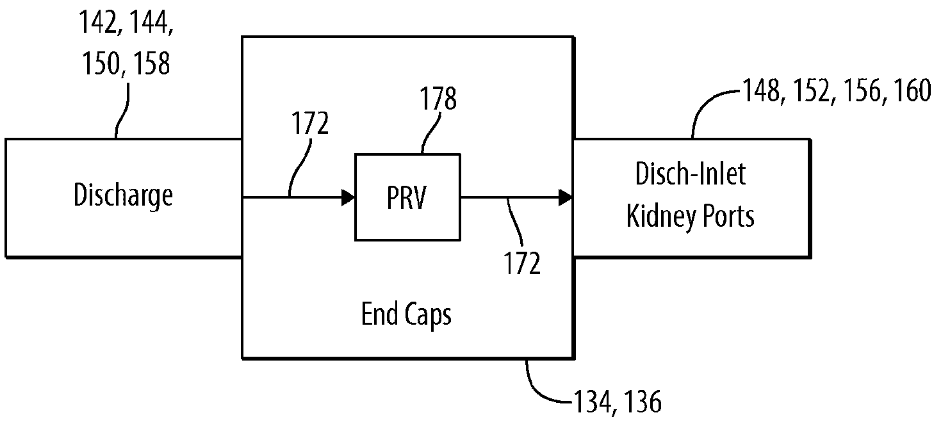

Fig. 7

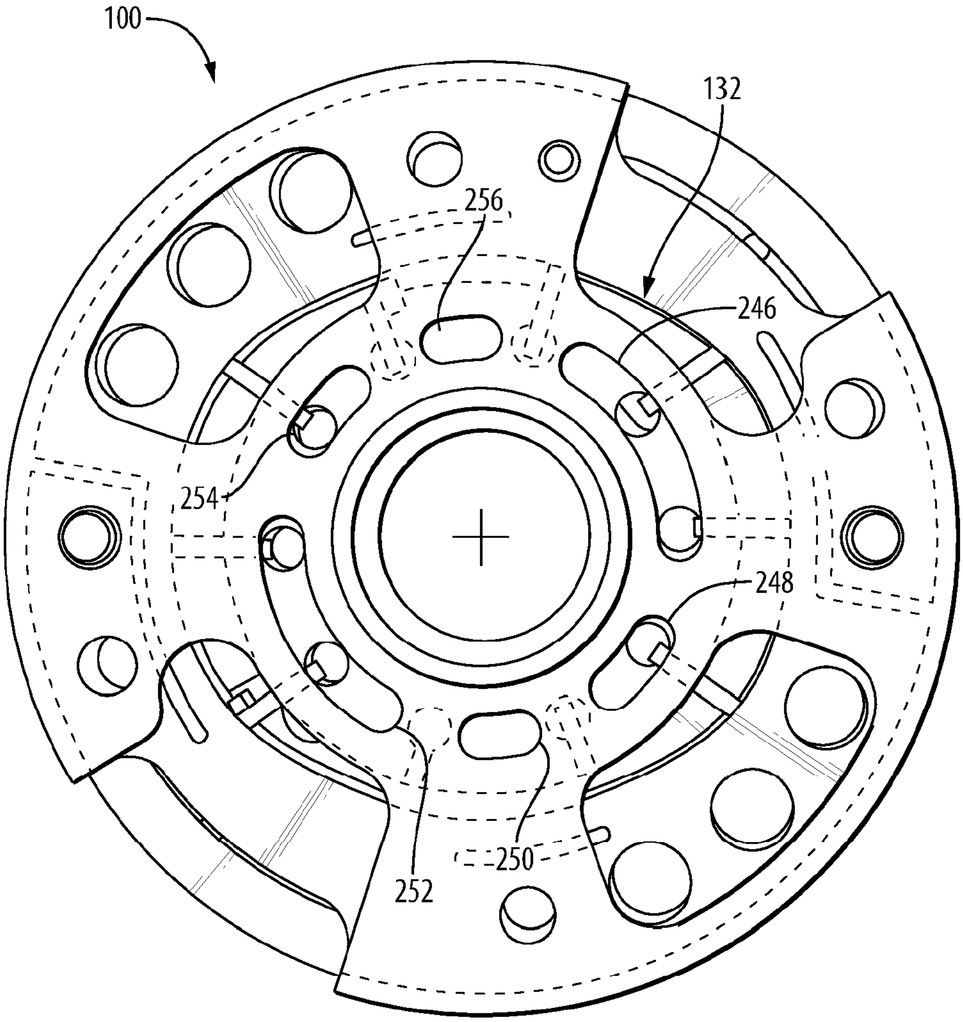

Fig. 8

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 24 20 1793

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2 641 195 A (WALTER FERRIS) 9 June 1953 (1953-06-09) * the whole document * * figures 1,2,5,6 * * claims 6-11 * * column 1, line 31 - line 40 * * column 4, line 16 - line 42 * * column 4, line 75 - column 5, line 15 * * column 5, line 33 - line 60 * * column 6, line 43 - line 63 * -----	1-15	INV. F01C21/08 F01C21/10 F04C2/344 F04C15/00

TECHNICAL FIELDS SEARCHED (IPC)
F01C
F04C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	13 January 2025	Sbresny, Heiko

1

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 24 20 1793

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-01-2025

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2641195 A	09-06-1953	NONE	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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 6634865 B **[0002]**
- US 7637724 B **[0002]**