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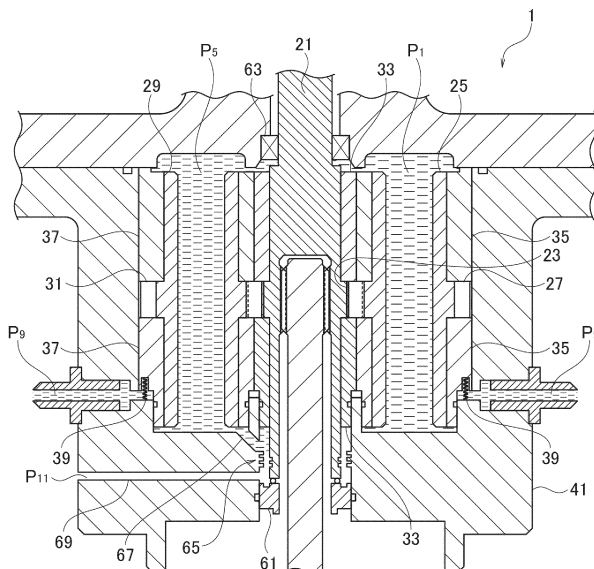
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Hoffmann****Patentanwlte PartG mbB****Paul-Heyse-Strae 29****80336 Mnchen (DE)**(71) Applicant: **IHI Corporation****Tokyo 135-8710 (JP)**(54) **TRIPLE GEAR PUMP**

(57) A triple gear pump with a drive gear and first and second idler gear respectively in mesh with the drive gear so as to respectively constitute first and second gear pumps for expelling fluid used as a fuel, is provided with: a housing enclosing the first gear pump and the second gear pump; a drive shaft linked to the drive gear so as to rotate unitarily with the drive gear and led out of the housing; a drive-shaft bearing rotatably supporting the

drive shaft and being axially floatingly movable, the drive-shaft bearing receiving pressure applied by the fluid so as to come in contact with the drive gear; a mechanical seal interposed between the drive shaft and the housing to prevent the fluid from leaking out of the housing; and a seal interposed between the drive-shaft bearing and the mechanical seal to prevent the pressure of the fluid from being transmitted to the mechanical seal.

FIG. 2

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Description**TECHNICAL FIELD**

[0001] The present disclosure relates to a triple gear pump with floating bearings, which uses rotating gears to pressurize and expel fluid, and in particular to a triple gear pump stably operative not only in a series or parallel mode but also in an unloaded mode.

BACKGROUND ART

[0002] A gear pump is generally provided with a pair of gears mutually in mesh and a housing accommodating the gears and, by rotating the pair of gears in a flow path defined by the housing, pressurizes and expels fluid therein. This is used as a fuel feeder for a reciprocating engine or a jet engine or such.

[0003] A floating bearing is often used in a gear pump. In the gear pump with the floating bearing, the bearing supports a gear shaft as well as slightly floats in the axial direction to come in contact with a gear side face and support it. The fluid passing through the gear pump serves for lubrication of the bearing as well as pressure application to the bearing onto the gear side face.

[0004] A triple gear pump has been proposed, in which one drive shaft drives two gear pumps simultaneously. The triple gear pump realizes a relatively small flow rate when these two gear pumps are operated in a series mode and a relatively large flow rate when operated in a parallel mode.

[0005] The patent literatures 1, 2 disclose related arts.

Citation List**Patent Literature****[0006]**

PTL 1: Japanese Patent Application laid-open No. 2008-50979

PTL 2: PCT International Publication WO 2017/009994 A1

SUMMARY OF THE INVENTION**PROBLEM TO BE SOLVED**

[0007] The floating bearing needs to be pressurized and, to assure smooth work and prevent fluid leakage from the gear side face, the applied pressure should be managed within a proper range. While the pressure of the fluid around the floating bearing is subject to fluctuations depending on operation modes, however, technical difficulty would increase if the number of operation modes were increased.

SOLUTION TO PROBLEM

[0008] The present disclosure relates to a triple gear pump that is capable of being stably operative not only in a series or parallel mode but also in an unloaded mode.

[0009] According to an aspect, a triple gear pump with a drive gear and first and second idler gear respectively in mesh with the drive gear so as to respectively constitute first and second gear pumps for expelling fluid used as a fuel, is provided with: a housing enclosing the first gear pump and the second gear pump; a drive shaft linked to the drive gear so as to rotate unitarily with the drive gear and led out of the housing; a drive-shaft bearing rotatably supporting the drive shaft and being axially floatingly movable, the drive-shaft bearing receiving pressure applied by the fluid so as to come in contact with the drive gear; a mechanical seal interposed between the drive shaft and the housing to prevent the fluid from leaking out of the housing; and a seal interposed between the drive-shaft bearing and the mechanical seal to prevent the pressure of the fluid from being transmitted to the mechanical seal.

EFFECTS OF THE INVENTION

[0010] The disclosed art provides a triple gear pump that is capable of being stably operative not only in a series or parallel mode but also in an unloaded mode.

BRIEF DESCRIPTION OF THE DRAWINGS**[0011]**

FIG. 1 is a schematic block diagram of a system for feeding fuel to an engine of an aircraft according to an embodiment.

FIG. 2 is a sectional plan view of a triple gear pump according to the embodiment.

FIG. 3 is a schematic cross-sectional view of the triple gear pump.

FIG. 4 is a sectional plan view mainly showing a floating bearing and its surroundings in the triple gear pump in an enlarged view.

FIG. 5 is schematic block diagrams describing a series mode, a parallel mode and an unloaded mode.

DESCRIPTION OF EMBODIMENTS

[0012] Certain embodiments will be described hereinafter with reference to the appended drawings. Throughout the following description and the appended claims, the terms "axial direction" and "around the axis" are defined and used with respect to each shaft.

[0013] Referring to FIG. 1, a triple gear pump 1 according to the present embodiment is to be incorporated in a system for feeding fuel to an engine 10 of an airplane and then pressurizes and expels fluid such as oil with rela-

tively low viscosity, namely kerosine for example.

[0014] The fluid is supplied from a tank through a flow path F_1 and is pressurized and expelled by the triple gear pump 1. For the purpose of starting the system or any other purpose, another low-pressure pump 3 may be interposed on the flow path F_1 . To the low-pressure pump 3 applied is, but not limited to, a centrifugal pump.

[0015] As a power source for the triple gear pump 1, energy extracted from a turbine of the engine 10 for example is applicable, and thus the amount of expelled fluid from the triple gear pump 1 is proportional to, or at least depends on, the rotating speed of the turbine. As sometimes the rotating speed is relatively high whereas the fuel consumption is relatively small particularly when the airplane cruises at a high altitude for example, the amount of expelled fluid does not necessarily meet the demand by engine 10. The expelled fluid, in the amount beyond the demand, is portioned out and fed back through a return path F_3 to the flow path F_1 so that the fluid only at the demanded amount is fed to the engine 10.

[0016] As lubricant oil L is circulated and heated in the engine 10, the expelled fluid is used for cooling it as well. Specifically, a flow path F_5 is in fluid communication with an oil cooler 9, and the fluid cools the lubricant oil L and in response receives heat, and thereafter the fluid is introduced through a feeding path F_7 to a combustion chamber 7 of the engine 10, thereby serving for combustion.

[0017] The triple gear pump 1 by itself generates heat, and some part of the heat turns back through the return path F_3 to the triple gear pump 1, and resultantly non-negligible temperature rise may occur in fluid in the flow path F_5 . Therefore a cooling capacity of the oil cooler 9 sometimes loses balance against rise in temperature of the lubricant oil L. An air-cooling oil cooler 11 by air A extracted from a bypass flow path or such of the engine 10 is thus used supplementally. With increase in a load on the air-cooling oil cooler 11, which is caused by increase of return flow through the return path F_3 and resultant rise in temperature of the expelled fluid, thermal stress on respective portions of the system will increase and some thermal energy will be exhausted in vain, thereby reducing energy efficiency. In a conventional triple gear pump, by enabling both a series mode and a parallel mode, increase and decrease of the amount of expelled fluid is enabled to minimize the amount of return flow.

[0018] The triple gear pump 1 according to the present embodiment, by enabling an unloaded mode as well as the series and parallel modes, enables further increase and decrease of the amount of expelled fluid and also enables improvement of energy efficiency. Specifically, the triple gear pump 1 enables a change from the series and parallel modes when the airplane idles on the ground and when it cruises at a high altitude for example, to a mode in which the triple gear pump 1 is released from load and then the fuel is mainly fed by the centrifugal pump 3 for example when it requires a great amount of fuel at a time of takeoff or such. The problem is difficulty in pressure control because high pressure should act on the

triple gear pump 1 throughout in the unloaded mode. Its solution will become apparent in the following descriptions.

[0019] Referring mainly to FIG. 3 in combination with FIGs. 2, 3, the triple gear pump 1 is generally provided with a drive gear 23 driven by a drive shaft 21 and first and second idler gears 27, 31 respectively driven by the drive gear 23, where the combination of the drive gear 23 and the first idler gear 27 constitutes a first gear pump G_1 and the combination of the drive gear 23 and the second idler gear 31 constitutes a second gear pump G_2 . The housing 41 encloses these elements and respective spaces 43, 45, 47 defined by the gear teeth and the housing 41, as being in close contact with tooth tops of these gears, serve to pressurize and transport fluid in accordance with gear rotation. The housing 41 is provided with a suction port 49 and a discharge port 51 both in fluid communication with the first gear pump G_1 , and further provided with a suction port 53 and a discharge port 55 both in fluid communication with the second gear pump G_2 . When the drive gear 23 is driven by an external power source to rotate about its axis, the first and second gear pumps G_1 and G_2 are set in operation in parallel so that fluid at a pressure P_1 is sucked through the suction port 49 is expelled under a pressure P_3 through the discharge port 51, and fluid at a pressure P_5 is sucked through the suction port 53 is expelled under a pressure P_7 through the discharge port 55. The discharge pressures P_3 , P_7 are usually higher than the suction pressures P_1 , P_5 , whereas these pressures depend on operation modes as described below.

[0020] Referring mainly to FIG. 2, the drive shaft 21 for coupling with the power source is led out of the housing 41 while shafts 25, 29 of the first and second idler gears 27, 31 are enclosed within the housing 41. These shafts 21, 25, 29 are respectively rotatably supported by floating bearings 33, 35, 37 which are respectively provided in pair. In addition, the floating bearings 33, 35, 37 respectively hold the gears 23, 27, 31 in therebetween. The floating bearings 33, 35, 37 are slightly floatingly movable in respective axial directions and receive applied pressure, thereby coming in contact with both sides of the gears 23, 27, 31 respectively.

[0021] Gaps are held respectively between both ends of the first and second idler shaft 25, 29 and the floating bearings 35, 37 and the housing 41 and are respectively in fluid communication with the suction ports 49, 53 so that the fluid flows therein and thus pressurize these end portions by means of the suction pressures P_1 , P_5 . These applied pressures are used for pressing the floating bearings 35, 37 respectively against the first and second idler gears 27, 31. To spread the fluid over these ends and equalize pressures thereon, the first and second idler shafts 25, 29 may be hollow for example. Further, to deliver these applied pressures to the floating bearings 33 of the drive shaft 21, a communication path 67 is interposed and establishes fluid communication between the floating bearings 37 and the floating bear-

ings 33.

[0022] To introduce an external pressure P_9 distinct from suction pressures P_1 , P_5 and apply it to the floating bearings 35, 37, introduction tubes may be provided on both side faces of the housing 41 for example. To receive the pressure P_9 , the floating bearings 35, 37 may be tapered toward corresponding ends and have steps on these shoulders, and internal ends of the introduction tubes may be opened to these shoulders. The step faces can serve for receiving the pressure P_9 . Any appropriate seals such as gaskets should be interposed between the ends and the shoulders in order to prevent pressure transmission. In addition, these introduction tubes may be made in fluid communication with either the discharge port 51 or the discharge port 55 for example and then the pressure P_9 applied to the step faces in principle matches with the discharge pressure P_3 or P_7 . To further regulate applied pressure, any pressurizing means such as springs 39 may be interposed between the shoulders and the housing 41. These are used for regulating pressures applied to the floating bearings 35, 37.

[0023] Between the housing 41 and the drive shaft 21, seals 61, 63 are interposed to prevent the internal fluid from leaking out. To one or both of the seals 61, 63 applicable are mechanical seals that use repulsive force by springs, for example, to press sealing faces against counter sealing faces. Not to apply excessive pressure to the mechanical seal, between the aforementioned communication path 67 and the seal 61 interposed is a seal 65 for preventing transmission of fluid pressure. To this seal 65, a labyrinth seal is applicable for example.

[0024] The housing 41 may be further provided with another introduction path 69 in order to retrieve fluid leaked out through the labyrinth seal and apply a proper pressure P_{11} to the mechanical seal 61. The introduction path 69 may be connected to the flow path F_1 for example so that the fluid before being given the pressure by the triple gear pump 1 can apply its original pressure to mechanical seal 61. Of course, instead any other proper flow path may be connected thereto.

[0025] Referring to FIG. 4 in combination with FIG. 2, a force f_1 originated from the suction pressure P_5 acts on the upper ends of the upper floating bearings 33, 37 and therefore a down force f_d presses the upper floating bearings 33, 37 against the drive gear 23 and the second idler gear 31. The force originated from the suction pressure P_5 also acts on the lower floating bearing 37 and further on the lower floating bearing 33 as the communication path 67 mediates so that an up force f_u presses the lower floating bearings 33, 37 against the drive gear 23 and the second idler gear 31. Because the common pressure acts thereon, the forces f_d , f_u are mutually in balance, thereby supporting the drive gear 23 and the second idler gear 31 stably. Further, by using a force f_2 distinct therefrom (normally greater), the up force f_u can be regulated, thereby preventing the floating bearing 37 from departing from the second idler gear 31.

[0026] While the aforementioned descriptions mainly

relates to the second gear pump G_2 , a balance among forces is similarly established in regard to the first gear pump G_1 .

[0027] The triple gear pump 1 shall be put in operation if connected to a fuel feeder system as shown in FIG. 5. Specifically, the flow path F_1 branches off into two paths respectively connected to an inflow path F_{11} and an inflow path F_{17} . Between the flow path F_1 and the inflow path F_{11} , a check or non-return valve V_1 may be interposed. The inflow paths F_{11} , F_{17} are respectively connected to the suction ports 49, 53 of the first and second gear pumps G_1 , G_2 . The discharge ports 51, 55 thereof are respectively connected to outflow paths F_{13} , F_{19} . The inflow path F_{11} also branches into two paths, one of which is connected via a valve V_3 to an outflow path F_{15} and is, after merging with the outflow paths F_{13} , F_{19} , connected to a flow path F_{21} . The flow path F_{21} is connected to the flow path F_5 .

[0028] Referring to FIG. 5(a) in combination with FIGs. 2 through 4, when the valve V_3 is closed, the triple gear pump 1 is in operation in a series mode. Then a relatively low pressure through the flow path F_1 is applied to both the inflow path F_{11} in communication with the suction port 49 of the first gear pump G_1 and the inflow path F_{17} in communication with the suction port 53 of the second gear pump G_2 . As the pressures P_1 , P_5 are both low then, the down and up forces f_d , f_u are mutually in balance on any of the floating bearings 33, 35, 37. The fluid pressurized and expelled out of the discharge port 51 flows through the flow paths F_{13} , F_{15} and the fluid expelled out of the discharge port 55 flows through the flow path F_{19} , and then the fluid merges together in the flow path F_{21} and is then fed to the engine 10.

[0029] Referring to FIG. 5(b) in place of FIG. 5(a), when the valve V_3 is opened, the triple gear pump 1 is in operation in a parallel mode. The exit pressure P_3 of the first gear pump G_1 acts on the inflow path F_{11} through the valve V_3 , and resultantly the suction pressure P_1 rises to match with the exit pressure P_3 . If the check valve V_1 is interposed there, the fluid is prevented from flowing backward toward the flow path F_1 . Even then the pressure P_1 commonly acts on both the floating bearings 35, thereby balancing the down and up forces f_d , f_u with each other. Any change in the pressure P_1 does not affect the floating bearings 33, 37. Then the first gear pump G_1 runs on idle (does no work) and only the second gear pump G_2 contributes to feeding the fluid.

[0030] To the valve V_3 , not a switching valve but a regulating valve such as a variable throttle valve is also applicable, which can continuously regulate the flow rate. In this case, while the valve V_3 can be set in medium states as well as the totally closed state (shown in FIG. 5(a)) and the totally opened state (shown in FIG. 5(b)), force balances on the floating bearings 33, 35, 37 would not be lost in any of the medium states.

[0031] Referring to FIG. 5(c) in place of FIG. 5(a) and FIG. 5(b), the present embodiment enables the unloaded mode. The valve V_3 is then kept open (or may be closed)

and the amount of expelled fluid from the centrifugal pump 3 is increased. Then high-pressure made by the centrifugal pump 3 is applied to both the gear pumps G_1 , G_2 . As will be understood from the above descriptions, the down and up forces f_d , f_u are mutually in balance on the floating bearing 33, let alone the floating bearings 35, 37, because the pressure reaches the floating bearing 33 of the drive shaft 21 through the communication path 67. Despite high-pressure application to the floating bearing 33, the labyrinth seal 65 bars the pressure from acting on the mechanical seal 61. Fluid leakage through the mechanical seal 61 does not occur, or smooth operation of the mechanical seal 61 is not spoiled.

[0032] In the unloaded mode, both the gear pumps G_1 , G_2 do no work substantially and mainly the centrifugal pump 3 alone contributes to feeding the fluid. The centrifugal pump can, particularly when the engine 10 outputs high power, efficiently expel a great amount of fluid. As being understood with reference again to FIG. 1, as the triple gear pump 1 does substantially no work and the return flow through the return path F_3 can be minimized, temperature rise of the fluid fed to the flow path F_5 can be suppressed. The cooling capacity of the oil cooler 9 can be sufficiently utilized and in turn the load on the oil cooler 11 can be suppressed.

[0033] The present embodiment allows selection of an optimum mode in response to a state of the airplane, for example selecting the parallel mode when the engine 10 rotates at relatively low speed but high power is required, selecting the series mode when the airplane cruises at a high altitude, and selecting the unloaded mode to mainly use the centrifugal pump when a particularly high power is required at a time of takeoff. The present embodiment can realize high energy efficiency in any of these modes.

[0034] Although certain embodiments have been described above, modifications and variations of the embodiments described above will occur to those skilled in the art, in light of the above teachings.

INDUSTRIAL APPLICABILITY

[0035] The disclosed art provides a triple gear pump that is capable of being stably operative not only in a series or parallel mode but also in an unloaded mode.

Claims

1. A triple gear pump with a drive gear and first and second idler gear respectively in mesh with the drive gear so as to respectively constitute first and second gear pumps for expelling fluid used as a fuel, comprising:

a housing enclosing the first gear pump and the second gear pump;
a drive shaft linked to the drive gear so as to rotate unitarily with the drive gear and led out of

the housing;
a drive-shaft bearing rotatably supporting the drive shaft and being axially floatingly movable, the drive-shaft bearing receiving pressure applied by the fluid so as to come in contact with the drive gear;
a mechanical seal interposed between the drive shaft and the housing to prevent the fluid from leaking out of the housing; and
a seal interposed between the drive-shaft bearing and the mechanical seal to prevent the pressure of the fluid from being transmitted to the mechanical seal.

2. The triple gear pump of claim 1, further comprising:

an idler shaft linked to the second idler gear;
a floating bearing rotatably supporting the idler shaft and being axially floatingly movable to axially come in contact with the second idler gear; and
a communication path establishing fluid communication within the housing between the drive-shaft bearing and the floating bearing, wherein the seal is interposed between the communication path and the mechanical seal.

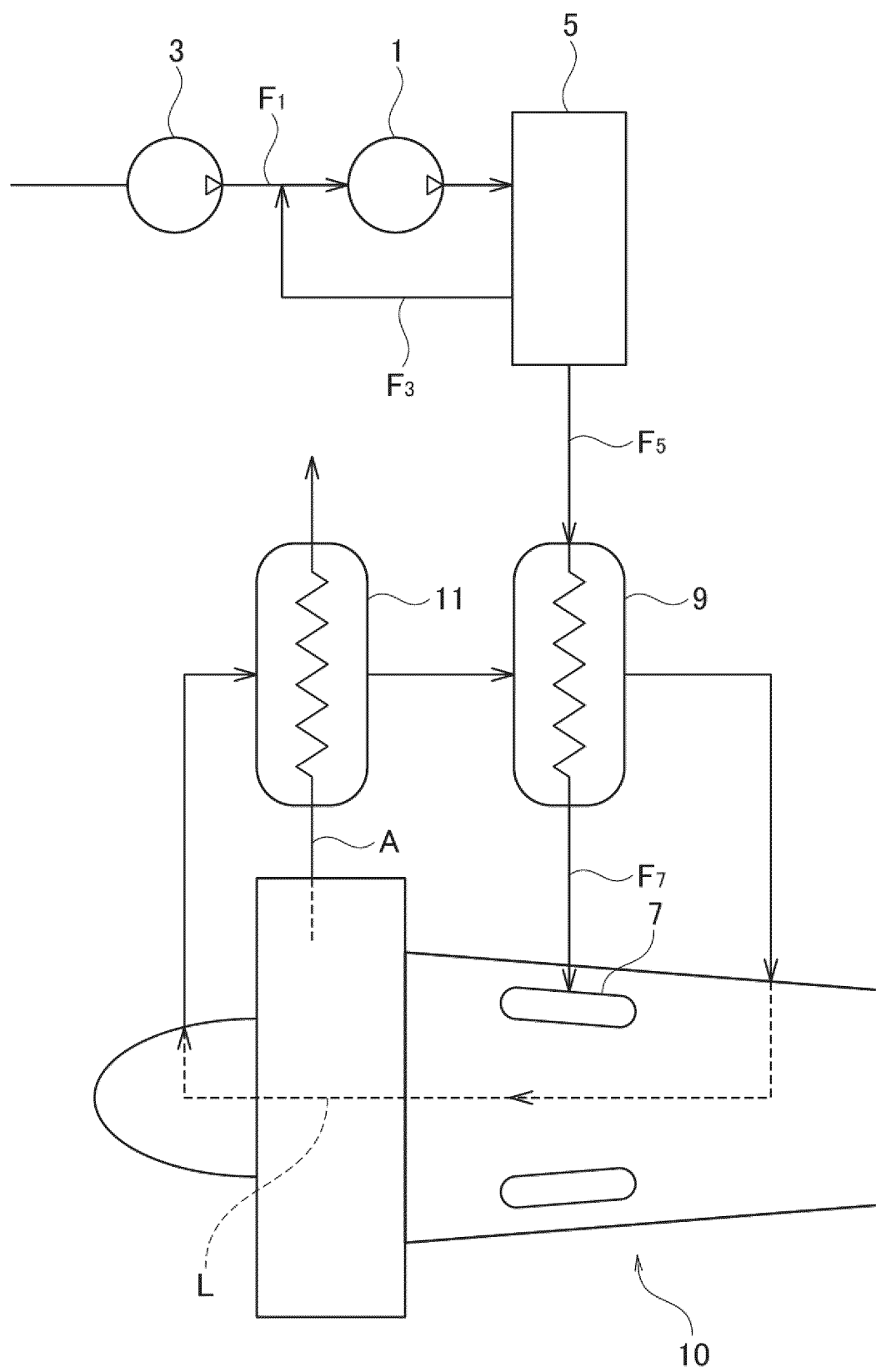
3. The triple gear pump of claim 2, further comprising:

a suction port opened in the housing and holding fluid communication with the second gear pump so as to introduce the fluid into the second gear pump, wherein the suction port is in fluid communication with the drive-shaft bearing, the floating bearing and the communication path so as to apply the pressure to drive-shaft bearing and the floating bearing.

4. The triple gear pump of claim 1, further comprising: an introduction path configured to introduce the fluid before being given the pressure from an outside of the housing.

5. The triple gear pump of any of claims 1 through 4, wherein the seal comprises a labyrinth seal.

FIG. 1



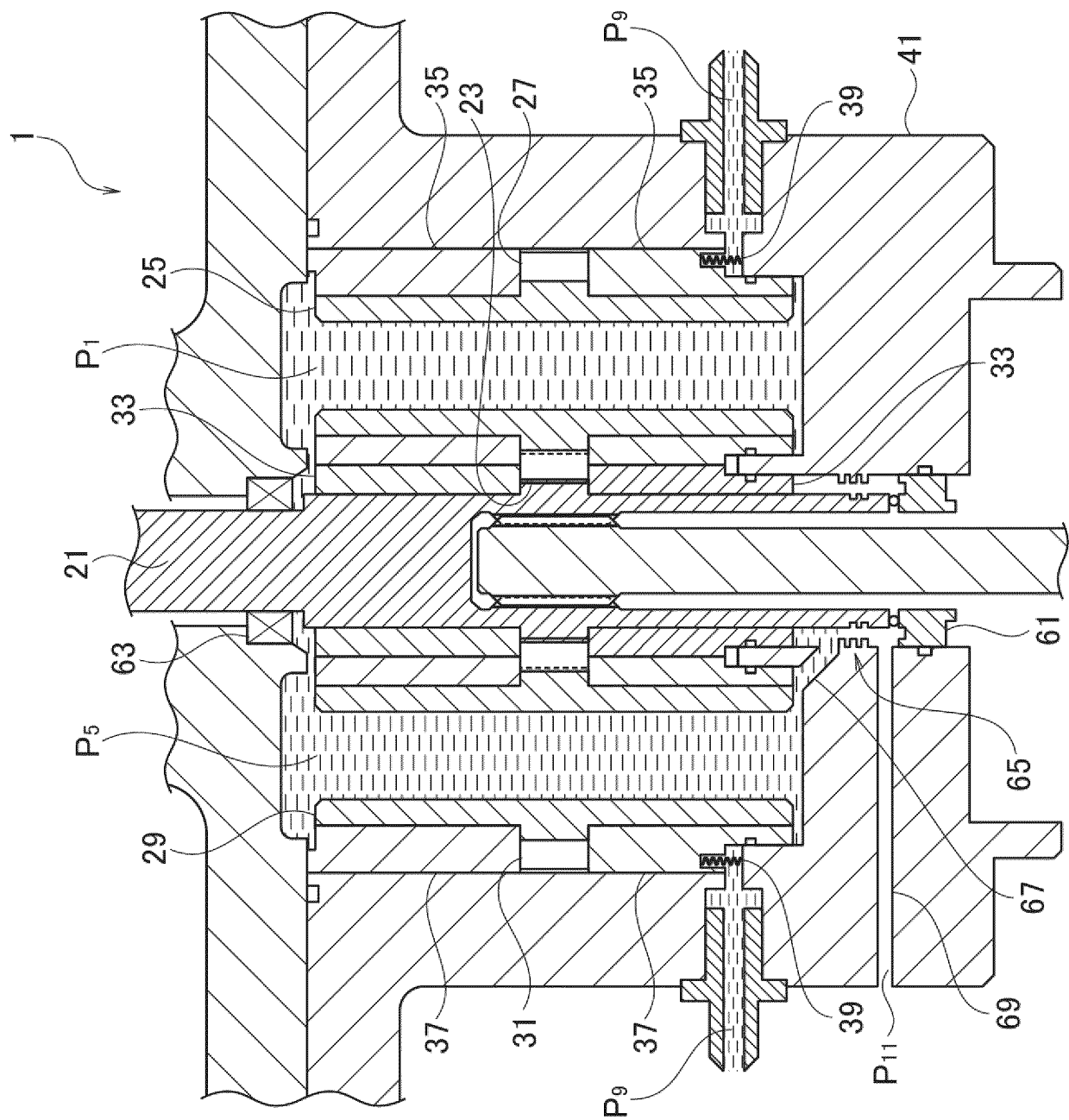


FIG. 2

FIG. 3

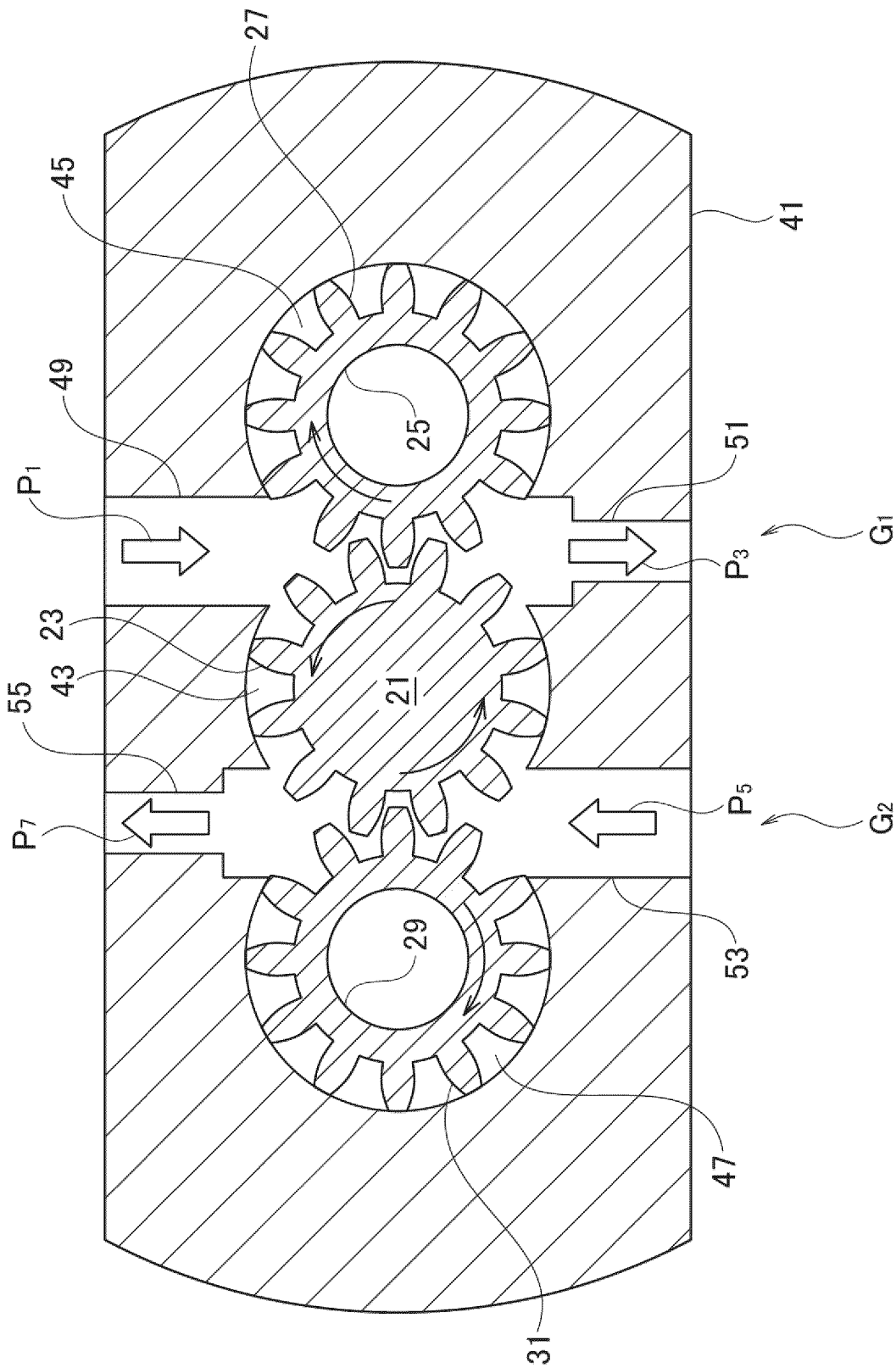


FIG. 4

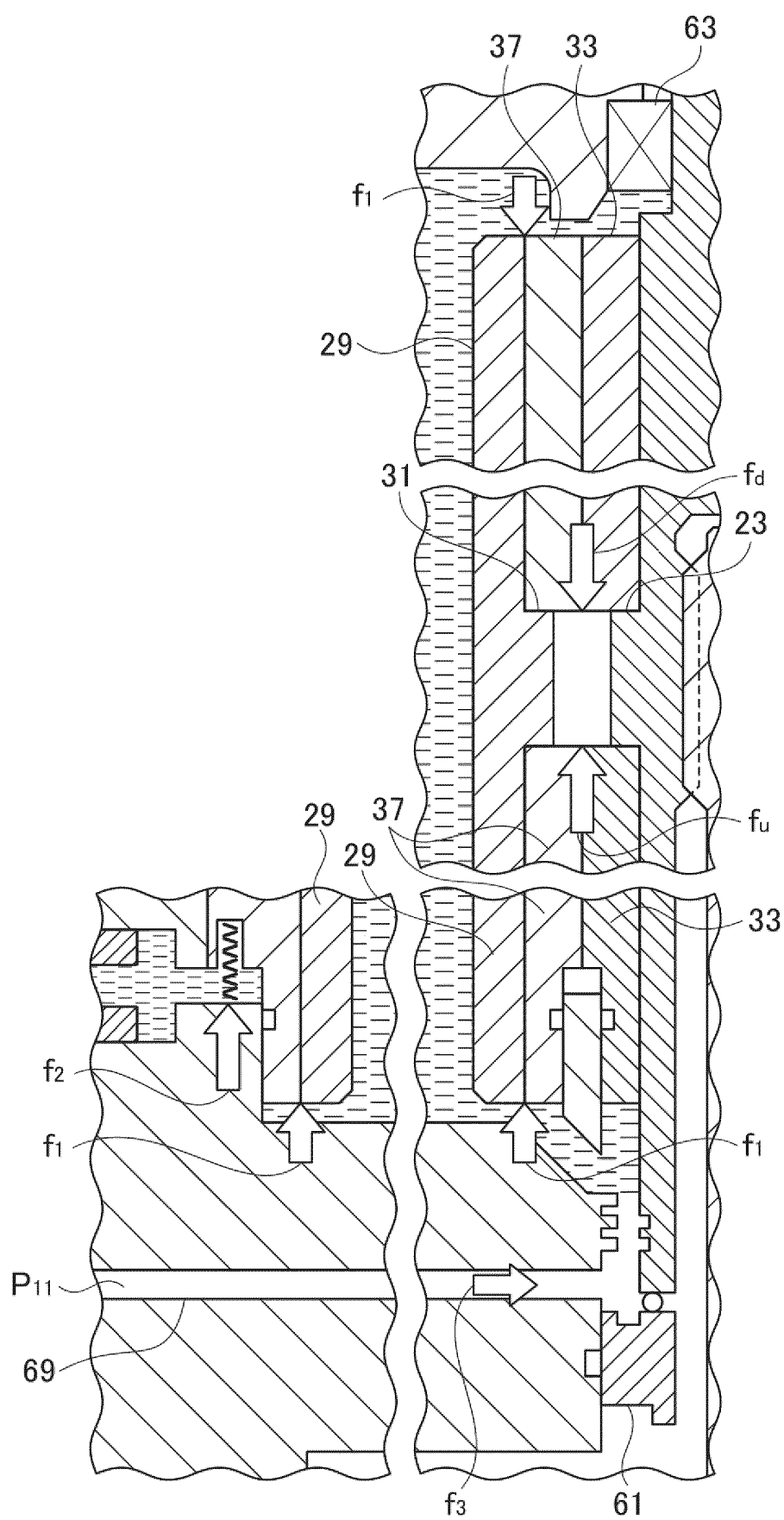
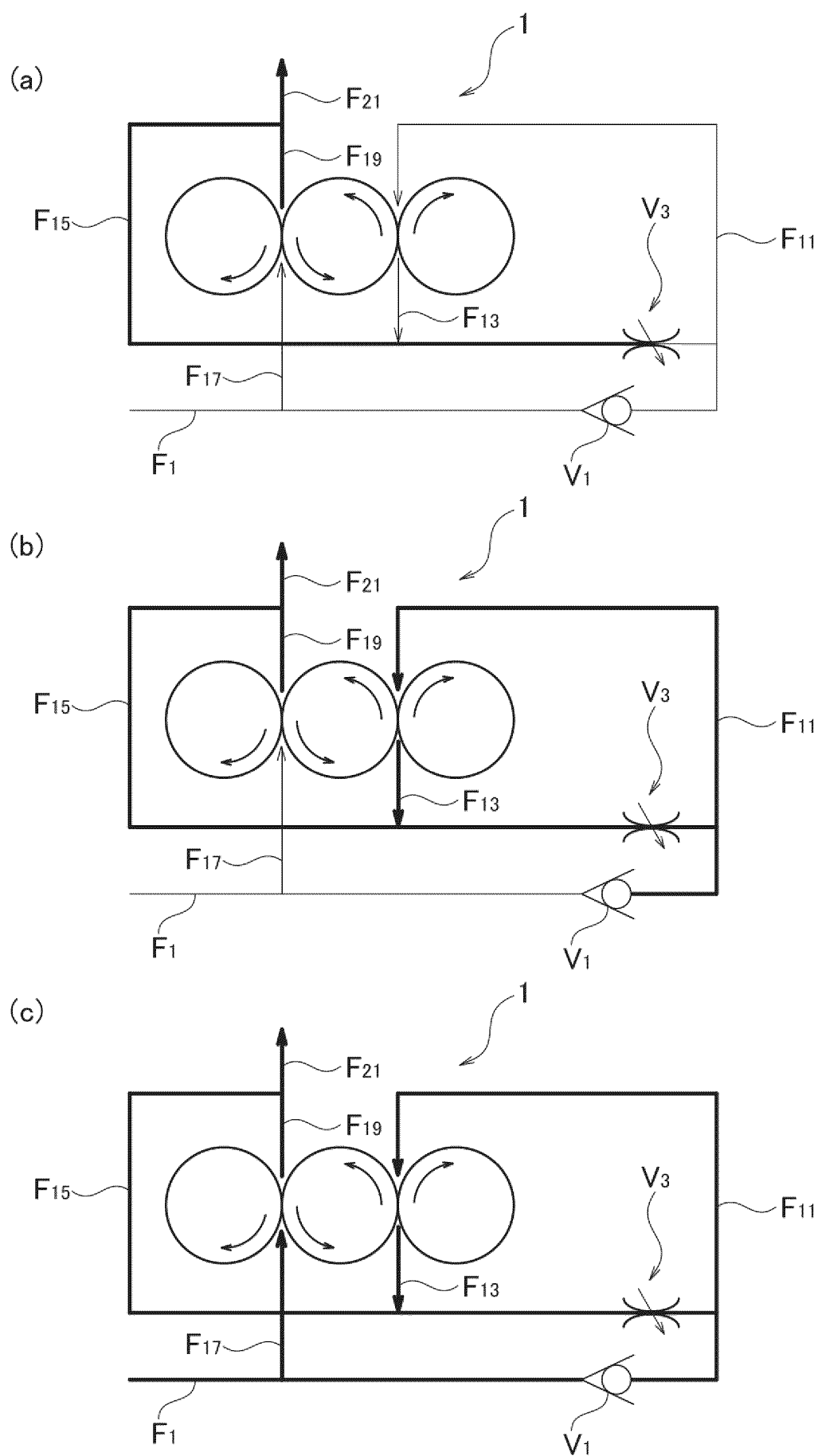


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/029919

A. CLASSIFICATION OF SUBJECT MATTER

F04C 11/00(2006.01)i
FI: F04C11/00 F

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04C11/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2017/009994 A1 (IHI CORP.) 19 January 2017 (2017-01-19) paragraphs [0012]-[0025], fig. 1, 2	1-5
Y	JP 04-164180 A (SHIMADZU CORP.) 09 June 1992 (1992-06-09) p. 2, upper left column, line 16 to p. 4, upper right column, line 1, fig. 1-5	1-5
Y	JP 2000-087872 A (SHIMADZU CORP.) 28 March 2000 (2000-03-28) paragraphs [0009]-[0013], fig. 1, 2	1-5
E, X	JP 2022-125574 A (IHI CORP.) 29 August 2022 (2022-08-29) claims 1-5	1-5

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

22 September 2022

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/029919

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Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2017/009994 A1	19 January 2017	US 2018/0106253 A1 paragraphs [0024]-[0037], fig. 1, 2 EP 3324048 A1	
JP 04-164180 A	09 June 1992	(Family: none)	
JP 2000-087872 A	28 March 2000	(Family: none)	
JP 2022-125574 A	29 August 2022	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008050979 A [0006]
- WO 2017009994 A1 [0006]