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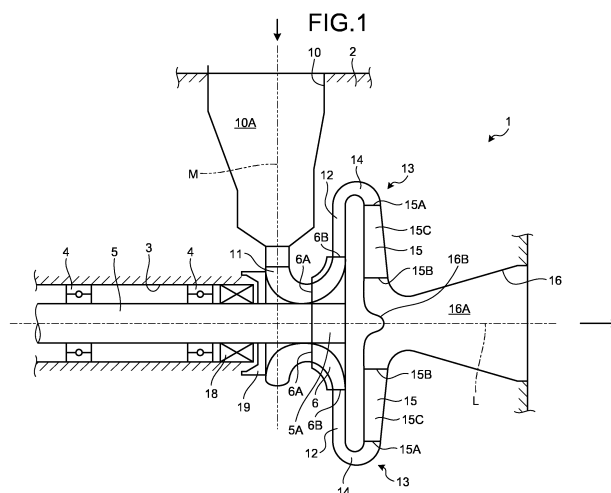
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(54) **CENTRIFUGAL COMPRESSOR**

(57) A centrifugal compressor that reduces pressure loss of fluid blown out from an impeller to improve efficiency is provided. The centrifugal compressor includes: a rotary shaft 5 rotatably supported by a casing 2; an impeller 6 provided on the rotary shaft 5 for blowing out fluid sucked from a suction port 10 in a radial direction

of the rotary shaft 5; a return channel 13 for reversing the fluid blown out from the impeller 6 toward an axis line L of the rotary shaft 5; and a discharge port 16 positioned on the axis line L of the rotary shaft 5 for discharging the fluid having passed through the return channel 13 in a direction along the axis line L.



## Description

### Field

**[0001]** The present invention relates to a centrifugal compressor.

### Background

**[0002]** Centrifugal compressors for industrial use are generally used in petrochemical plants or natural gas plants, for example. In the centrifugal compressors of this type, kinetic energy is given to fluid by the rotation of an impeller, and an increase in pressure due to centrifugal force is obtained by blowing out the fluid in a radially outer direction.

**[0003]** In the centrifugal compressors of this type, a configuration in which a scroll passage formed in a spiral shape in a circumferential direction is provided on an outlet side of an impeller and fluid blown out from the impeller is discharged to the outside of a casing via the scroll passage has been known in conventional techniques (see Patent Literature 1, for example). The scroll passage is formed so as to have a gradually-increasing cross-sectional area toward an outlet thereof in the circumferential direction, for example. Pressure loss of the fluid can be reduced by causing the fluid to flow through the scroll passage through the use of a circumferential velocity component of the fluid.

### Citation List

#### Patent Literature

**[0004]** Patent Literature 1: Japanese Patent Application Laid-Open No. 61-66899

### Summary

#### Technical Problem

**[0005]** By the way, the applications of the centrifugal compressors of this type have a tendency to be specialized in recent years. For example, a low-head centrifugal compressor with a large discharge flow rate has been demanded. In fluid blown out from an impeller, the radial velocity component thereof becomes larger than the circumferential velocity component thereof at a large discharge flow rate. Thus, in the configuration including the scroll passage, an impeller with a larger flow rate has a larger spiral flow in a meridional cross-section of the scroll passage at an inlet of the scroll passage, which is an outlet of a diffuser, due to its increased radial velocity component. Consequently, smooth flow in the scroll passage is hindered, thereby increasing a pressure loss coefficient of the scroll passage and thus deteriorating the efficiency of the centrifugal compressor.

**[0006]** The present invention has been made in view

of such circumstances, and it is an object of the present invention to provide a centrifugal compressor that reduces pressure loss of fluid blown out from an impeller to improve the efficiency thereof.

#### Solution to Problem

**[0007]** According to an aspect of the present invention, a centrifugal compressor comprises: a rotary shaft rotatably supported by a casing; an impeller provided on the rotary shaft for blowing out fluid sucked from a suction port in a radial direction of the rotary shaft; a return channel for reversing the fluid blown out from the impeller toward the rotary shaft; and a discharge port positioned on an axis line of the rotary shaft for discharging the fluid having passed through the return channel in a direction along the axis line.

**[0008]** According to this configuration, the provision of the return channel for reversing the fluid blown out from the impeller toward the rotary shaft and the discharge port positioned on the axis line of the rotary shaft for discharging the fluid having passed through the return channel in the direction along the axis line allows the fluid blown out from the impeller to be guided to the discharge port without using the scroll passage. The scroll passage has a larger pressure loss coefficient than the return channel. A difference between those pressure loss coefficients increases with an increase in flow coefficient. Thus, an impeller with a larger flow coefficient can improve the efficiency of the centrifugal compressor further by changing the scroll passage to the return channel. Moreover, since the discharge port is positioned on the axis line of the rotary shaft and discharges the fluid having passed through the return channels in the direction along the axis line, the fluid having passed through the return channels can be discharged without interfering with each other.

**[0009]** Advantageously, in the centrifugal compressor, a bearing for pivotally supporting the rotary shaft is provided on a shaft end closer to the discharge port than the bearing. According to this configuration, the impeller is supported by the rotary shaft in a so-called cantilever (referred to also as overhung) state. This eliminates a need to provide a sealing member between the impeller and the discharge port, thus achieving a simplified structure.

**[0010]** Advantageously, in the centrifugal compressor, the suction port is provided in a direction orthogonal to an axial direction of the rotary shaft. According to this configuration, the suction port can be disposed while preventing interference with the bearing of the rotary shaft, etc. Thus, the size of the casing can be prevented from increasing in the axial direction.

**[0011]** Advantageously, in the centrifugal compressor, the return channel includes a return vane on an outlet side of the return channel. The return vane has a relatively small pressure loss coefficient as compared to the scroll passage. Thus, the efficiency of the centrifugal

compressor can be further improved when the flow rate is increased, for example. Also, in the centrifugal compressor, the impeller may be provided singularly to perform single-stage compression.

#### Advantageous Effects of Invention

**[0012]** According to the present invention, the provision of the return channel for reversing the fluid blown out from the impeller toward the rotary shaft and the discharge port positioned on the axis line of the rotary shaft for discharging the fluid having passed through the return channel in the direction along the axis line allows the fluid blown out from the impeller to be guided to the discharge port without using the scroll passage. The scroll passage has a larger pressure loss coefficient than the return channel. A difference between those pressure loss coefficients increases with an increase in flow coefficient. Thus, an impeller with a larger flow coefficient can improve the efficiency of the centrifugal compressor further by changing the scroll passage to the return channel. Moreover, since the discharge port is positioned on the axis line of the rotary shaft and discharges the fluid having passed through the return channels in the direction along the axis line, the fluid having passed through the return channels can be discharged without interfering with each other.

#### Brief Description of Drawings

##### **[0013]**

FIG. 1 is a longitudinal cross-sectional view of a centrifugal compressor according to a present embodiment.

FIG. 2 is a graph comparing relationships between flow coefficients and pressure loss coefficients in a scroll passage and a return channel.

#### Description of Embodiments

**[0014]** An embodiment of the present invention will be described below with reference to the drawings. Note that this invention is not limited by the following embodiment. Note also that elements in the following embodiment encompass those substitutable by and obvious to a person skilled in the art, or substantially the same elements.

**[0015]** FIG. 1 is a longitudinal cross-sectional view of a centrifugal compressor of the present embodiment. A centrifugal compressor 1 is used as a low-head (for example, a pressure ratio of about 1.05) compressor for feeding fluid, such as gas or air, at a large flow rate (for example, about 5.0 m<sup>3</sup>/s) into a predetermined pressure vessel in a chemical plant, for example.

**[0016]** As shown in FIG. 1, the centrifugal compressor 1 includes: a casing 2 formed by the combination of a plurality of parts; a rotary shaft 5 supported so as to be

rotatable about an axis line L via bearings 4, 4 in a space 3 formed in the casing 2; and a closed type impeller 6 fixed to the rotary shaft 5 so as to rotate integrally with the rotary shaft 5. In the present embodiment, the impeller 6 is fixed to a shaft end 5A of the rotary shaft 5 positioned external to the bearings 4 (upper side in FIG. 1). Thus, the impeller 6 is supported by the rotary shaft 5 in a so-called cantilever (referred to also as overhung) state. Note that the impeller 6 is not limited to the closed type having a blade part and a shroud part integrated together as in the present embodiment. An open type without the shroud part may be employed instead.

**[0017]** The centrifugal compressor 1 is a single-stage centrifugal compressor including a single impeller 6. In the centrifugal compressor 1, the rotary shaft 5 is driven by a driving mechanism (not shown) to rotate the impeller 6. Consequently, fluid, such as gas or air, to be compressed is sucked into the centrifugal compressor 1 via a suction port 10 provided in the casing 2.

**[0018]** The suction port 10 has an opening in a direction along a perpendicular line M perpendicular to the axis line L of the rotary shaft 5. An intake passage 11 is connected to the suction port 10 via a suction space 10A formed in the casing 2. The intake passage 11 curves along the direction of the axis line L of the rotary shaft 5 (axial direction) and has an opening facing an intake port 6A of the impeller 6. The centrifugal compressor 1 also includes a vaneless diffuser 12 provided radially to the axis line L of the rotary shaft 5 and a return channel 13 on the side of a blowoff port 6B of the impeller 6. The vaneless diffuser 12 constitutes a passage for converting kinetic energy of the fluid having centrifugal force given by the impeller 6 into pressure energy and sending out the pressure energy.

**[0019]** The return channel 13 is a passage for reversing the direction of the fluid blown out in a radially outer direction by the impeller 6 and the vaneless diffuser 12 toward the rotary shaft 5, i.e., in a radially inner direction. The return channel 13 includes a return bend 14 continuous with the vaneless diffuser 12, and a return passage 15. Outlets 15B of the return passages 15 are each connected to a discharge space 16A provided in the casing 2. The discharge space 16A is positioned on the axis line L of the rotary shaft 5. In the discharge space 16A, a discharge port 16 is opened so as to discharge the fluid along the axis line L.

**[0020]** The return passage 15 is formed so as to have a gradually-increasing passage area (cross-sectional area) from an inlet 15A of the return passage 15 toward the outlet 15B. A return vane 15C for regulating the flow of the fluid is provided in the return passage 15.

**[0021]** The fluid having passed through the vaneless diffuser 12 and flowing into the return channel 13 has a radial velocity component and a circumferential velocity component. In a configuration having a large discharge flow rate as in the present embodiment, the radial velocity component tends to be larger than the circumferential velocity component. The return vane 15C regulates the

flow of the fluid so as to suppress the circumferential velocity component of the fluid flowing into the return channel 13 (return passage 15). Consequently, the fluid mainly having the radial velocity component flows at the outlet 15B of the return passage 15. Thus, no spiral velocity component is wasted as in an outlet of a scroll passage. Such an effect can also reduce pressure loss of the fluid further in the return channel 13.

**[0022]** The fluid having flowed through the respective return passages 15 flows into the discharge space 16A and mixed together in the discharge space 16A. A guide protrusion 16B that protrudes toward the discharge port 16 is provided on the axis line L at the bottom of the discharge space 16A. The guide protrusion 16B guides the flow of the fluid having flowed into the discharge space 16A so as to be changed in the direction of the axis line L. The fluid discharged from the discharge port 16 is sent out to a discharge pipe (not shown).

**[0023]** A shaft seal 18 for keeping airtightness and a balance piston 19 are disposed between the bearing 4 and the intake passage 11 in the space 3 in which the rotary shaft 5 is disposed. The shaft seal 18 prevents the communication between the aforementioned space 3 and a path including the impeller 6, etc., through which the fluid flows.

**[0024]** In the present embodiment, the centrifugal compressor 1 includes the return channel 13 for reversing the fluid blown out from the impeller 6 toward the axis line L of the rotary shaft 5. As mentioned above, in a configuration having a large discharge flow rate, fluid tends to have a radial velocity component larger than its circumferential velocity component. The return vane 15C provided on the outlet side of the return channel 13 (the return passage 15) regulates the flow of the fluid so as to suppress the circumferential velocity component of the fluid flowing into the return passage 15. Consequently, the fluid mainly having the radial velocity component flows at the outlet 15B of the return passage 15. In the present embodiment, the centrifugal compressor 1 includes the discharge port 16 positioned on the axis line L of the rotary shaft 5 for discharging the fluid having passed through the return channel 13 in the direction along the axis line L. This allows the fluid having passed through the return channels 13 and each having the radial velocity component to be mixed together without interfering with each other and smoothly discharged from the discharge port 16.

**[0025]** According to the present embodiment, the centrifugal compressor 1 includes the bearings 4 for pivotally supporting the rotary shaft 5 and the impeller 6 is provided on the shaft end 5A closer to the discharge port 16 than the bearings 4. Thus, the impeller 6 is supported by the rotary shaft 5 in a so-called cantilever state. This eliminates a need to provide a sealing member between the impeller 6 and the discharge port 16, thus simplifying the structure of the centrifugal compressor 1.

**[0026]** According to the present embodiment, the suction port 10 is provided in the direction of the perpendicular

line M orthogonal to the axis line L of the rotary shaft 5. Accordingly, the suction port 10 can be disposed in the casing 2 while preventing interference with the bearing 4 of the rotary shaft 5, etc. Thus, the size of the casing 2 can be prevented from increasing in the direction of the axis line L.

**[0027]** According to the present embodiment, the return channel 13 includes the return vane 15C in the return passage 15 disposed on the outlet side of the return channel 13. Thus, the return vane 15C regulates the flow of the fluid so as to suppress the circumferential velocity component of the fluid flowing into the return channel 13 (return passage 15). Consequently, the fluid mainly having the radial velocity component flows at the outlet 15B of the return passage 15. Moreover, the return vane 15C has a relatively small pressure loss coefficient as compared to the case with the scroll passage. Thus, the efficiency of the centrifugal compressor 1 can be further improved when the flow rate is increased.

**[0028]** The functions and effects of the centrifugal compressor 1 according to the present embodiment will be described next. FIG. 2 is a graph comparing relationships between flow coefficients and pressure loss coefficients in the scroll passage and the return channel. In FIG. 2, three kinds of impellers A to C having different flow coefficients  $\phi$  are used. These impellers A to C are provided in conventional centrifugal compressors each including the scroll passage and in the centrifugal compressors 1 of the present embodiment each including the return channel 13. Pressure loss coefficients  $\zeta$  when such centrifugal compressors are operated are measured. Here, the flow coefficient  $\phi$  increases in the order of the impeller A, the impeller B, and the impeller C.

**[0029]** In the configuration including the scroll passage provided on the outlet side of the impellers A to C, it can be seen that the impeller C having a larger flow coefficient  $\phi$  has a larger pressure loss coefficient  $\zeta$  (see alternate long and short dash lines in FIG. 2). As mentioned above, the fluid blown out from the impeller has a radial velocity component and a circumferential velocity component. The radial velocity component increases with an increase in flow rate.

**[0030]** The scroll passage, on the other hand, is a passage formed in a spiral shape in the circumferential direction. Thus, while the fluid of the circumferential velocity component smoothly flows through the scroll passage, the fluid of the radial velocity component hinders the flow in the circumferential direction. Therefore, if the impeller having a large flow rate (flow coefficient  $\phi$ ) is employed, pressure loss when flowing through the scroll passage increases, thus resulting in reduced efficiency of the centrifugal compressor as shown in FIG. 2.

**[0031]** In the configuration including the return channel provided on the outlet side of the impellers A to C, in contrast, the fluid of the radial velocity component smoothly flows in the return channel 13 as mentioned above. As shown by solid lines in FIG. 2, the pressure loss coefficient  $\zeta$  is substantially the same regardless of

the magnitude of the flow coefficient  $\phi$ . Furthermore, the return passage 15 on the outlet side of the return channel 13 includes the return vane 15C, and the return vane 15C regulates the flow of the circumferential velocity component. Consequently, the fluid mainly having the radial velocity component flows out from the return channel 13. With the return channel 13, no hindering of the flow due to a spiral flow in a meridional cross section as in the scroll passage occurs, or no spiral velocity component is wasted at the outlet of the scroll passage. Thus, pressure loss when flowing through the return channel 13 can be reduced, thus improving the efficiency of the centrifugal compressor 1.

**[0032]** Another embodiment will be described next. While the centrifugal compressor 1 in the above-described embodiment is configured to include the separately-provided driving mechanism for driving the rotary shaft 5, the centrifugal compressor 1 may have a sealed structure in which an electric motor as a driving mechanism and a compressor are integrally included in a casing. According to this structure, the electric motor and the compressor are integrally provided in the casing, and the casing is sealed, for example. This eliminates a need to provide a sealing member (see the shaft seal 18 in FIG. 1) between the electric motor and the impeller 6, thus simplifying the configuration of the centrifugal compressor.

**[0033]** While the impeller 6 in the above-described embodiment has the cantilever supporting structure in which the impeller 6 is provided on the shaft end 5A of the rotary shaft 5, the present invention is not limited thereto. A bearing for pivotally supporting the rotary shaft 5 may be provided on the shaft end 5A between the impeller 6 and the discharge space 16A provided in the casing 2. In this case, the employment of a magnetic bearing, for example, as the bearing eliminates a need to provide, for example, a lubricating oil path for feeding a lubricating oil to the bearing. Thus, shaft vibration can be reduced while maintaining the simplified device configuration. Note that a general bearing to which a lubricating oil is fed can be used if a space for providing the lubricating oil path can be allocated.

**[0034]** While the above-described embodiment has described the single-stage compressor including the single impeller 6 provided in the casing 2, the present invention is not limited thereto. For example, if rotor dynamics permit, a plurality (two or three, for example) of impellers 6 may be disposed on the rotary shaft 5, and an outlet of the upstream impeller 6 and an inlet of the downstream impeller 6 may be connected with the return channel 13. Such a configuration can achieve the improvement of efficiency at a large flow rate in the multi-stage centrifugal compressor 1 as well.

Reference Signs List

**[0035]**

1	centrifugal compressor
2	casing
3	space
4	bearing
5	5 rotary shaft
5A	shaft end
6	impeller
6A	intake port
6B	blowoff port
10	10 suction port
10A	suction space
11	intake passage
12	vaneless diffuser
13	return channel
15	15 return bend
15	return passage
15A	inlet
15B	outlet
15C	return vane
20	20 16 discharge port
16A	discharge space
16B	guide protrusion
18	shaft seal
19	balance piston
25	25 A, B, C impeller
L	axis line
M	perpendicular line

### 30 Claims

#### 1. A centrifugal compressor comprising:

a rotary shaft rotatably supported by a casing;  
an impeller provided on the rotary shaft for blowing out fluid sucked from a suction port in a radial direction of the rotary shaft;  
a return channel for reversing the fluid blown out from the impeller toward the rotary shaft; and  
a discharge port positioned on an axis line of the rotary shaft for discharging the fluid having passed through the return channel in a direction along the axis line.

2. The centrifugal compressor according to claim 1, comprising a bearing for pivotally supporting the rotary shaft, wherein the impeller is provided on a shaft end closer to the discharge port than the bearing.

3. The centrifugal compressor according to claim 1 or 2, wherein the suction port is provided in a direction orthogonal to an axial direction of the rotary shaft.

4. The centrifugal compressor according to any one of claims 1 to 3, wherein the return channel includes a return vane on an outlet side of the return channel.

5. The centrifugal compressor according to any one of

claims 1 to 4, wherein the impeller is provided singularly to perform single-stage compression.

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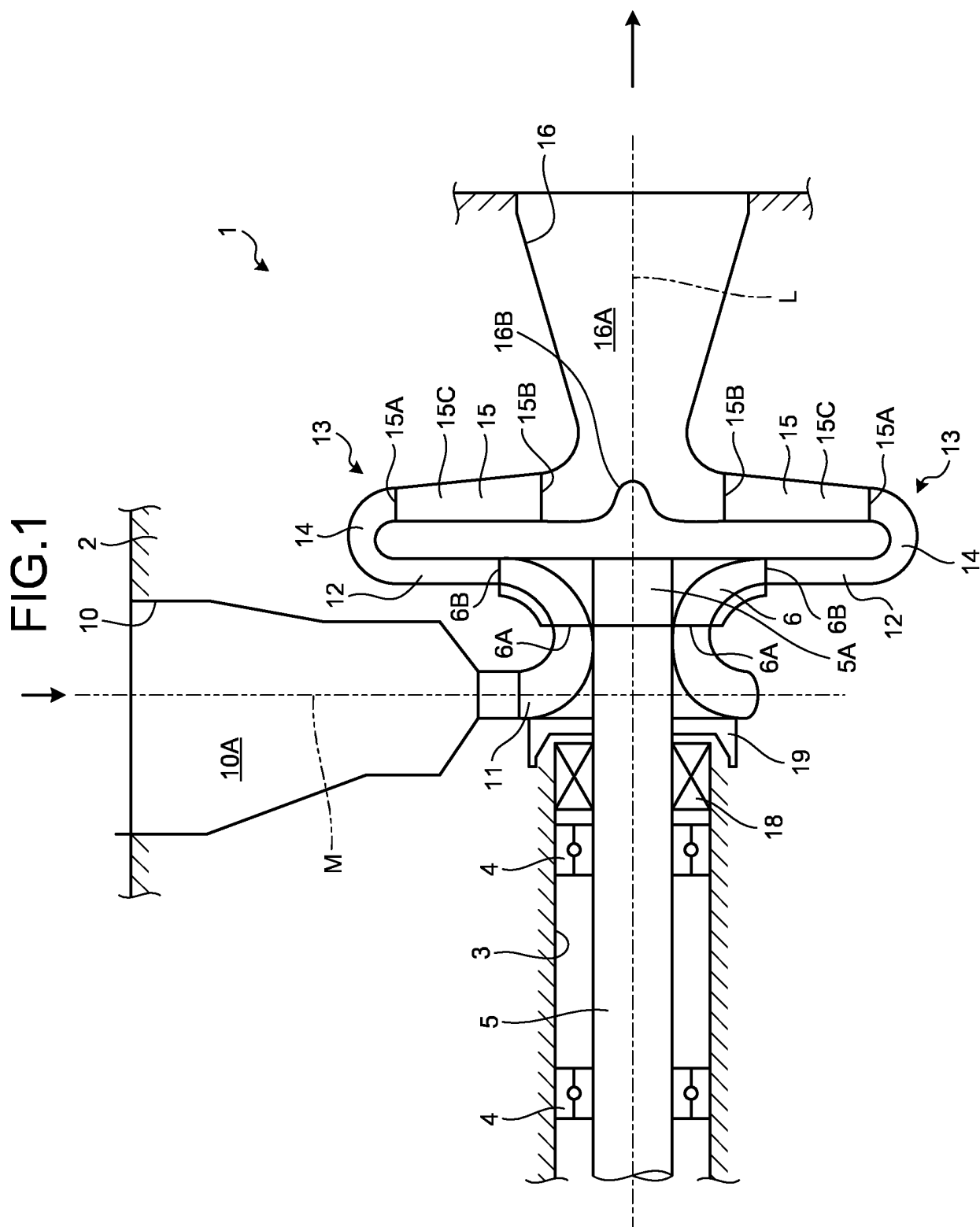
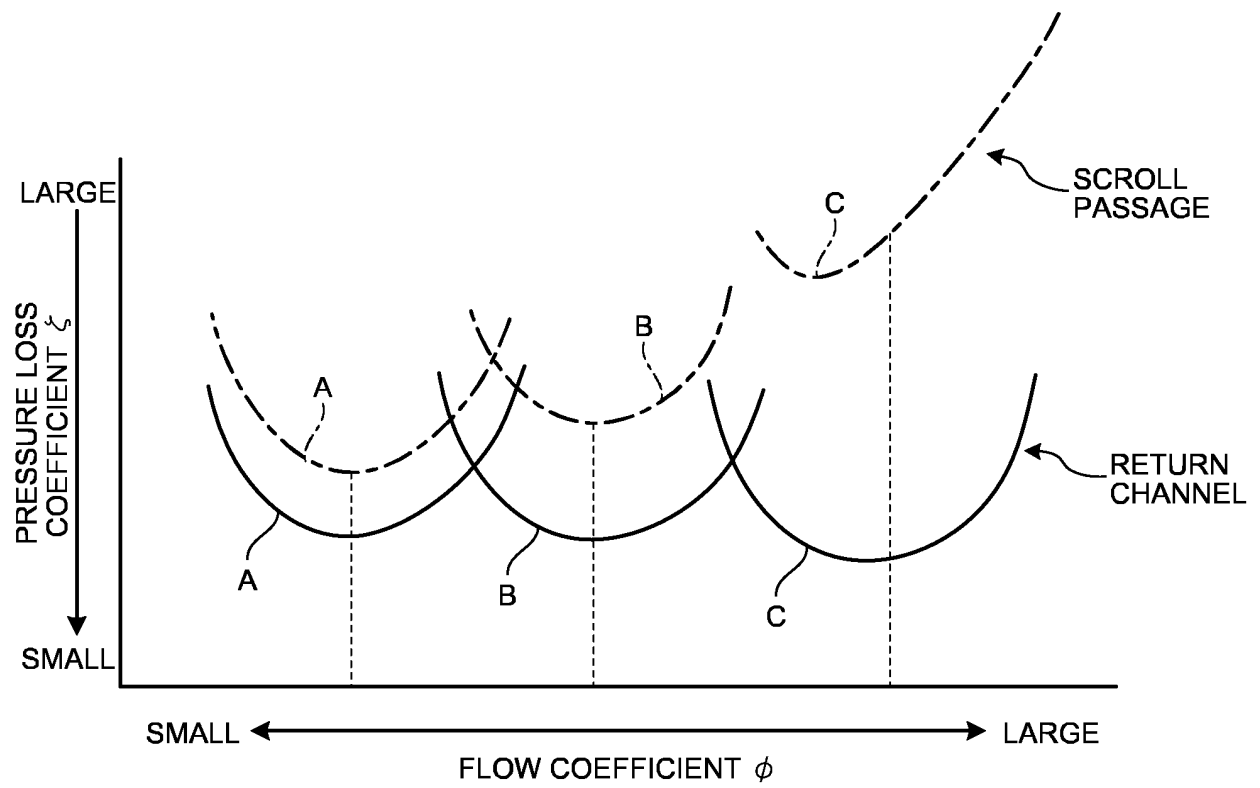


FIG.2





## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/059342

## A. CLASSIFICATION OF SUBJECT MATTER

F04D29/44(2006.01)i

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F04D29/44

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015

Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2004-300929 A (The Tokyo Electric Power Co., Inc.), 28 October 2004 (28.10.2004), paragraph [0012]; fig. 1 (Family: none)	1, 5 3, 4 2
X A	US 4693669 A (Leroy K. ROGERS, SR), 15 September 1987 (15.09.1987), column 3, line 26 to column 6, line 48; fig. 1 (Family: none)	1 2-5
Y	JP 2003-293995 A (Mitsubishi Heavy Industries, Ltd.), 15 October 2003 (15.10.2003), paragraph [0011]; fig. 1 (Family: none)	3

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

☐ See patent family annex.

\* Special categories of cited documents:

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Date of the actual completion of the international search  
08 June 2015 (08.06.15)Date of mailing of the international search report  
30 June 2015 (30.06.15)Name and mailing address of the ISA/  
Japan Patent Office  
3-4-3, Kasumigaseki, Chiyoda-ku,  
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/059342

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2011-252424 A (Hitachi Plant Technologies, Ltd.), 15 December 2011 (15.12.2011), paragraph [0022]; fig. 1 (Family: none)	4

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 61066899 A [0004]