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(54) **GAS TURBINE ENGINE**

(57) A gas turbine engine (1) comprises a hollow rotor (11) including a plurality of rotor segments stacked and coupled together in a direction of its center axis (C) and defining at least one of a compressor (3) and a turbine (7); and a pipe unit (51) inserted into an inner space (29) of the rotor in the center axis direction. In the gas turbine engine (1), a weight distribution of the pipe unit (51) within an axial transverse section is set eccentric with respect to the center axis (C) of the rotor. In this way, a gas turbine engine which is high in performance and reliability is provided, in which a pipe provided in an inner space of the rotor to transport a cooling medium or lay out a cable, etc., is prevented from whirling.

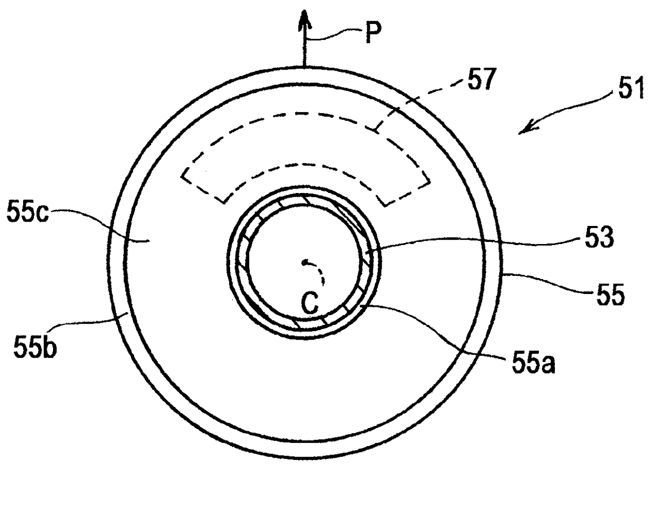

Fig. 3A

EP 2 543 851 A1

Description

Technical Field

[0001] The present invention relates to a gas turbine engine including a pipe for use as a passage of a cooling medium, a cable layout member, or the like.

Background Art

[0002] In a gas turbine engine which takes out driving power by high-temperature combustion gas generated by combusting air compressed in a compressor, it is necessary to cool the interior of the engine, to improve performance and life of the engine. As a structure for cooling the interior of the gas turbine engine, it is proposed that a pipe is extended axially inside of a rotor constituting a turbine and is used as a cooling medium passage (e.g., Patent Literature 1).

Citation Lists

Patent Literature

[0003] Patent Literature 1: Japanese Laid-Open Patent Application Publication No. Hei. 11-257012

Summary of the Invention

Technical Problem

[0004] In general, a compressor rotor or a turbine rotor in a gas turbine engine is assembled in such a manner that a plurality of rotor segments are coupled together in a center axis direction thereof. Therefore, it is difficult to form a pipe in an inner space of the rotor integrally with the rotor and fasten the pipe to the rotor by means of a fastener member such as a bolt, in terms of productivity. Therefore, it is necessary to insert the pipe into a through-hole provided inside of the rotor before or after assembling of the rotor. In this case, however, a small gap is unavoidably formed between the pipe and a peripheral wall of the through-hole. As a result, when the rotor is rotating at a high speed, the pipe whirls inside the through-hole, which causes a problem that efficiency and life of the gas turbine engine are reduced.

[0005] The present invention is directed to solving the above mentioned problem, and an object of the present invention is to provide a gas turbine engine which can prevent whirl of a pipe provided in an inner space of a rotor to transport a cooling medium or lay out cables, for example, and thus can achieve higher performance and reliability.

Solution to Problem

[0006] To achieve the above describe object, a gas turbine engine of the present invention comprises a hollow rotor including a plurality of rotor segments coupled together in a direction of its center axis and defining at least one of a compressor and a turbine; and a pipe unit inserted into an inner space of the rotor in the center axis direction, wherein a weight distribution of the pipe unit within an axial transverse section is eccentric with respect to the center axis of the rotor.

[0007] In accordance with this configuration, since the pipe unit is provided in the inner space of the hollow rotor and is utilized as a cooling medium passage or a cable layout member, higher performance and higher functionality of the gas turbine engine can be achieved, while suppressing an increase in a dimension of the overall gas turbine engine. Since the weight distribution of the pipe unit is made eccentric, the pipe unit is displaced only in a specified direction with respect to the rotor, during rotation of the rotor. This makes it possible to suppress the pipe unit from whirling inside of the rotor. Therefore, reliability of the gas turbine engine can be maintained.

[0008] In the gas turbine engine of the present invention, preferably, the pipe unit includes a pipe member and a flange provided on an outer periphery of the pipe member and fitted to an inner peripheral surface of the rotor. In this case, preferably, a weight distribution of the flange within the axial transverse section is eccentric with respect to the center axis of the rotor. Since the flange is provided on the outer periphery of the pipe member, it becomes easy to mount the pipe unit to the rotor and position the pipe unit with respect to the rotor. Moreover, since the weight distribution of the flange within the axial transverse section is made eccentric, the pipe unit which is eccentric can be manufactured easily.

[0009] In the gas turbine engine of the present invention, the pipe unit may constitute a passage of a cooling medium for cooling an interior of the gas turbine engine or a passage of seal air for sealing a bearing supporting the rotor such that the rotor is rotatable. In accordance with this configuration, by utilizing the inner space of the rotor, the interior of the engine can be cooled or sealed. Therefore, characteristics such as efficiency and life of the engine can be improved, while suppressing an increase in a dimension of the gas turbine engine.

[0010] When in the gas turbine engine of the present invention, the pipe unit constitutes the cooling medium passage, or the seal air passage, the rotor may be a compressor rotor, and the cooling medium or the seal air may be compressed air extracted from the compressor. In accordance with this configuration, the cooling or sealing of the interior of the gas turbine engine can be performed efficiently by utilizing the compressed air of the compressor, without introducing air for cooling or sealing.

[0011] In the gas turbine engine of the present invention, a cable may be extended to inside of the pipe unit. In accordance with this configuration, by extending, for example, a wire used to transmit a measurement signal of a temperature sensor, a strain sensor, etc., to inside of the pipe unit, as the cable, higher functionality of the gas turbine engine can be achieved by utilizing the inner space of the rotor.

Advantageous Effects of the Invention

[0012] As described above, in accordance with the gas turbine engine of the present invention, it is possible to prevent whirl of a pipe mounted to the inner peripheral surface of a rotor to allow a cooling medium to be transported therethrough or a cable to be inserted thereinto, and as a result, performance and reliability of the gas turbine engine can be improved.

Brief Description of the Drawings

[0013]

[Fig. 1] Fig. 1 is a side view showing a gas turbine engine according to Embodiment 1 of the present invention, a part of which is cut away.
[Fig. 2] Fig. 2 is a longitudinal sectional view showing major components of the gas turbine engine of Fig. 1.
[Fig. 3A] Fig. 3A is a front view showing an example of a pipe unit for use in the gas turbine engine of Fig. 1.
[Fig. 3B] Fig. 3B is a front view showing an example of the pipe unit for use in the gas turbine engine of Fig. 1.
[Fig. 3C] Fig. 3C is a longitudinal sectional view showing an example of the pipe unit for use in the gas turbine engine of Fig. 1.
[Fig. 4] Fig. 4 is a cross-sectional view showing a modified example of the pipe unit for use in the gas turbine engine of Fig. 1.
[Fig. 5] Fig. 5 is a cross-sectional view showing a gas turbine engine according to Embodiment 2 of the present invention, a part of which is cut away.
[Fig. 6] Fig. 6 is a longitudinal sectional view showing an enlarged part of Fig. 4.
[Fig. 7] Fig. 7 is a cross-sectional view showing a gas turbine engine according to Embodiment 3 of the present invention, a part of which is cut away.
[Fig. 8] Fig. 8 is a longitudinal sectional view showing an enlarged part of Fig. 7.

Description of the Embodiments

[0014] Hereinafter, an embodiment of the present invention will be described with reference to the drawings.

[0015] Fig. 1 shows a gas turbine engine (hereinafter simply referred to as gas turbine) according to Embodiment 1 of the present invention. Referring to Fig. 1, a gas turbine 1 is configured such that a compressor 3 compresses air IA introduced from outside and guides the compressed air to a combustor 5, a fuel F is injected to the interior of the combustor 5 and combusted therein, and the resulting high-temperature and high-pressure combustion gas G drives a turbine 7. In description below, in some cases, a compressor side of the gas turbine 1 in a center axis direction will be referred to as "front side" and a turbine side of the gas turbine 1 in the center axis direction is referred to as "rear side."

[0016] In the present embodiment, the compressor 3 is of an axial-flow type. The axial-flow compressor 3 includes a compressor rotor 11 constituting the front portion of a rotary section of the gas turbine 1. The compressor rotor 11 is divided into two sections, i.e., front and rear sections. Specifically, the compressor rotor 11 includes a compressor rotor body 11A which is the front section, and a compressor rotor extending section 11B coupled to the rear end portion of the compressor rotor body 11A by means of a bolt (not shown) such that the compressor rotor extending section 11B is unable to rotate relative to the compressor rotor body 11A. A number of rotor vanes 13 are arranged on the outer peripheral surface of the compressor rotor body 11A. By combining the rotor vanes 13 and a number of stator vanes 17 arranged on the inner peripheral surface of a housing 15, the air IA suctioned from an air-intake tube 19 through a space between the housing 15 and an inner cowling 20 located radially inward relative to the housing 15 is compressed. The compressed air CA is supplied to the combustor 5 via a diffuser 21 disposed downstream of the compressor 3.

[0017] The compressor rotor 11 includes a plurality of compressor rotor segments 23 stacked together and coupled together in a center axis direction of the compressor rotor 11. Each compressor rotor segment 23 includes a disc 25 forming a radially inward portion. The plurality of rotor vanes 13 are implanted on the outer peripheral portion of the disc 25 at equal intervals in a circumferential direction. The compressor rotor 11 has a hollow shape. Each compressor rotor segment 23 has a through-hole 27 penetrating the center portion of the disc 25 in the center axis direction. Thus, the compressor rotor 11 entirely has a hollow portion 29 defined by the through-holes 27.

[0018] A plurality of combustors 5 are arranged at equal intervals in the circumferential direction of the gas turbine 1. In the combustor 5, the compressed air CA supplied from the compressor 3 is mixed with the fuel F injected to the interior of the combustor 5 and combusted therein, and the resulting high-temperature and high-pressure combustion gas G flows into the turbine 7 through a turbine nozzle (first stator vane) 23.

[0019] The turbine 7 includes a turbine rotor 33 constituting the rear portion of the rotary section of the gas turbine 1 and a turbine casing 35 covering the turbine rotor 33. A plurality of turbine stator vanes 37 are attached on the inner peripheral portion of the turbine casing 35 at predetermined intervals. The turbine rotor 33 is provided with a plurality of turbine rotor vanes 39 positioned downstream of the turbine stator vanes 37, respectively. The two rotors 11, 33 are entirely rotatably supported on the housing 15 via a front bearing 43, a center bearing 45, and a rear bearing 47.

[0020] A pipe unit 51 is inserted into the hollow portion

29 of the compressor rotor 11 in a direction of a rotor center axis C. Specifically, the pipe unit 51 includes a plurality of steel-made pipe members 53 having an outer diameter smaller than a hole diameter of the through-hole 27 and a plurality of steel-made flanges 55 provided on the outer peripheries of the pipe members 53. The pipe unit 51 is inserted into the hollow portion 29 of the compressor rotor 11 from forward. A front end portion 51a of the pipe unit 51 is fastened to the compressor rotor 11 via a disc-shaped support member 56 positioned at a front end portion 11a of the compressor rotor 11.

[0021] As shown in Fig. 2, the plurality of pipe members 53 are arranged in series along the rotor center axis C. Adjacent pipe members 53 are coupled together by a flange 55. More specifically, the flange 55 includes an inner peripheral wall 55a fitted to the outer peripheral portions of the end portions of the pipe members 53 facing each other, an outer peripheral wall 55b fitted to the inner peripheral surface 11b of the compressor rotor 11, and a coupling wall 55c coupling the peripheral walls 55a, 55b together. The two pipe members 53 are welded to the inner peripheral wall 53a and thereby joined together. Between the outer peripheral wall 55b of the flange 55 and the inner peripheral surface 11b of the compressor rotor 11, a slight gap S is present to allow the flange 55 to be inserted into the through-hole 27. Although as shown in Fig. 1, a plurality of (six in the present embodiment) flanges 55 are provided at axially different locations, only one flange 55 may be provided.

[0022] As shown in Fig. 3, the pipe unit 51 is configured to have an eccentric weight distribution within an axial transverse section perpendicular to the rotor center axis C (hereinafter referred to as "weight distribution"), the weight distribution being eccentric with respect to the rotor center axis C. As a structure for allowing pipe unit 51 to have the eccentric weight distribution, preferably, the weight distribution of the flange 55 is made eccentric with respect to the rotor center axis C.

[0023] Specifically, for example, as shown in Fig. 3A, a weight 57 is embedded in a portion of the coupling wall 55c of the flange 55 to allow the weight distribution to be eccentric. Or, as shown in Fig. 3B, a portion of the coupling wall 55c of the flange 55 may be cut out to provide an axial through-hole 59. Or, as shown in Fig. 3C, a thinned-wall portion 61 may be provided by thinning a portion of the coupling wall 55c of the flange 55.

[0024] The weight distribution of the pipe unit 51 may be made eccentric with a small amount. For example, the outer peripheral wall 55b of the flange 55 may be pressed against the inner peripheral surface 11b of the compressor rotor 11 by rotating the flange 55 integrally with the compressor rotor 11, in a range of a rotational speed which is no less than 60% of a rated rotational speed of the compressor rotor 11.

[0025] Since the pipe unit 51 is configured such that the flange 55 is provided on the outer periphery of the pipe member 53 as described above, it becomes easy to mount the pipe unit 51 to the rotor and position the pipe unit 51 with respect to the rotor. In addition, by making the weight distribution of the flange 55 eccentric, it becomes easy to manufacture the pipe unit 51 having an eccentric weight distribution.

[0026] The structure of the pipe unit 51 is not limited to the example of Fig. 1 including the pipe member 53 and the flange 55, so long as the pipe unit 51 has an inner space extending axially and its weight distribution is eccentric. For example, as shown in the cross-section of Fig. 4, the flange 55 may be omitted, and the pipe unit 51 may consist of the pipe member 53. If the pipe unit 51 consists of the pipe member 53, for example, the thickness of the inner peripheral wall 53a may be set asymmetric with respect to the rotor center axis C. Thus, the weight distribution of the pipe unit 51 can be made eccentric.

[0027] In the present embodiment, as shown in Fig. 1, the pipe unit 51 forms a passage (cooling medium passage) RP of a cooling medium RA for cooling the interior of the gas turbine 1. The pipe unit 51 extends from the front end portion 11a of the compressor rotor 11 to the rear end portion 11c of the compressor rotor 11. The front end portion 51a of the pipe unit 51 penetrates a support member 56 and communicates with a compressed air extraction passage 63. The rear end portion 51b of the pipe unit 51 opens toward the turbine rotor 33. Therefore, the compressed air CA extracted from the compressor 3 via the compressed air extraction passage 63 is guided to a region in the vicinity of the turbine rotor 33 through the cooling medium passage RP inside of the pipe member 53 and cools the turbine rotor 33 as the cooling medium RA.

[0028] In the above configuration, the interior of the gas turbine can be cooled by utilizing the hollow portion 29 which is the inner space of the compressor rotor 11. Therefore, characteristics such as efficiency and life of the engine can be improved while suppressing an increase in a dimension of the gas turbine 1. Since the compressed air CA extracted from the compressor 3 is used as the cooling medium RA, the cooling of the interior of the gas turbine 1 can be performed efficiently without introducing air for cooling. Since the weight distribution of the pipe unit 51 is eccentric, the flange 55 of the pipe unit 51 is pressed against the inner peripheral surface 11b of the compressor rotor 11 by a centrifugal force in an eccentric direction P as shown in Fig. 3A, according to the rotation of the pipe unit 51 together with the compressor rotor 11. As a result, the pipe unit 51 is stably supported on the compressor rotor 11 and will not whirl.

[0029] Fig. 5 is a longitudinal sectional view showing the gas turbine engine 1 according to Embodiment 2 of the present invention. In Embodiment 2, the pipe unit 51 is formed as a passage SP of seal air for sealing the center bearing 45, rather than the cooling medium passage of Embodiment 1. Embodiment 2 is identical to Embodiment 1 except for the following.

[0030] Fig. 6 is a longitudinal sectional view showing a region surrounding the center bearing 45, in an enlarged manner. As shown in Fig. 6, a bearing housing 65 which is a first bearing case is coupled to the downstream end portion of the inner peripheral wall of the diffuser 21, by means of a bolt which is not shown. The bearing housing 65 covers an axial center portion of the compressor rotor extending section 11B at which the center bearing 45 is located. A bearing box 67 which is a second bearing case is provided inward relative to the bearing housing 65. A bearing chamber 60 is formed to accommodate the center bearing 45, radially inward relative to the bearing box 67. Air seal mechanisms 69 are provided at both sides axially outward relative to the bearing chamber 60.

[0031] The air seal mechanism 69 is a seal mechanism for preventing high-temperature air LA which has leaked from the compressor 3 or high-temperature gas LG which has leaked from the combustor 5 from entering the bearing chamber 60 through a vent chamber 71 communicating with outside of the engine. The vent chamber 71 is a space between the bearing housing 65 and the bearing box 67.

[0032] The compressor rotor extending section 11B is provided with through-holes extending from the hollow portion 29 to the air seal mechanisms 69, as seal air introduction passages 79 for providing communication between the center portion 29 and the air seal mechanisms 69. A rear end portion 51b of the pipe member 53 of the pipe unit 51 is closed. Air output holes 81 which are radial through-holes are provided on the peripheral wall of a portion of the compressor rotor extending section 11B which is inserted into the hollow portion 29.

[0033] The compressed air CA which has been extracted from the compressor 3 through the compressed air extraction passage 63 of Fig. 5, passes through the seal air passage SP, and then is supplied as seal air SA to the air seal mechanisms 69 via the air output holes 81 and the seal air introduction passages 79 of Fig. 6. A portion of the seal air SA supplied to the air seal mechanisms 69 flows out to the vent chamber 71, and prevents the high-temperature air from flowing into the bearing chamber 60.

[0034] In accordance with the gas turbine 1 of Embodiment 2, the interior of the gas turbine can be sealed by utilizing the hollow portion 29 which is the inner space of the compressor rotor 11. Therefore, characteristics such as efficiency and life of the engine can be improved while suppressing an increase in a dimension of the gas turbine 1. Since the compressed air CA extracted from the compressor 3 is used as the seal air SA, the sealing of the interior of the gas turbine 1 can be performed efficiently without introducing air for cooling or sealing.

[0035] Fig. 7 is a cross-sectional view showing a gas turbine according to Embodiment 3 of the present invention. In Embodiment 3, a measurement cable 85 is extended to inside of the pipe unit 51. Embodiment 3 is identical to Embodiment 1 except for the following.

[0036] In the present embodiment, the pipe unit 51 is extended from the front end portion 11a of the compressor rotor 11 to the rear end portion 11c of the compressor rotor 11. The cable 85 is used to take out a measurement signal of a temperature of the turbine rotor 33 attached with rotor vanes of the turbine 7. Specifically, one end of the cable 85 is connected to a temperature sensor 87 attached on the turbine rotor 33, while the other end of the cable 85 is connected to a telemeter transmitter 89.

[0037] The telemeter transmitter 89 is a device for transmitting the measurement signal by radio. Fig. 8 is an enlarged cross-sectional view showing a region surrounding the front end portion 11a of the compressor rotor 11 of Fig. 7. As shown in Fig. 8, the telemeter transmitter 89 is mounted to an annular support 91 fastened to the front end portion 11a of the compressor rotor 11 together with the support member 56, by means of a bolt 90, and is rotatable with the compressor rotor 11. The telemeter transmitter 89 has a transmission antenna 93 on its an inner peripheral portion. Radially inward relative to the transmission antenna 93 of the telemeter transmitter 89, a receiving antenna 95 of a telemeter receiver (not shown) is supported on an inner cowling 20 which is a non-rotating member of the compressor 3 and faces the transmission antenna 93 in a radial direction. The measurement signal of the temperature sensor 87 of Fig. 7 is transmitted to the telemeter receiver installed outside via the cable 85, the transmission antenna 93 and the receiving antenna 95.

[0038] In the present embodiment, description has been given of an example in which the sensor connected to one end of the cable 85 is the temperature sensor 87. A measurement element connected to the cable 85 is not limited to the temperature sensor 87, but may be various measurement devices such as a strain sensor or a rotation sensor. Furthermore, the cable 85 is not limited to the measurement cable 85 described in the present embodiment, but may be cables for various purposes as necessary such as control signal transmission or electric power transmission for a device installed inside. In this configuration, higher functionality and higher performance of the gas turbine engine can be achieved, by efficiently utilizing the hollow portion 29 which is the inner space of the compressor rotor 11.

[0039] Since the cable 85 inside the pipe unit 51 is not fastened to the interior of the pipe unit 51, it will whirl inside the pipe member 53 of the pipe unit 51, when it is rotating together with the compressor rotor 11 and the pipe unit 51. However, since the weight distribution of the pipe unit 51 within the axial transverse section is eccentric, it becomes possible to prevent the pipe unit 51 from whirling in the hollow portion 29 of the pipe unit 51 by the influence of the whirl of the cable 85.

[0040] As described above, since the pipe unit 51 provided in the inner space of the rotor is utilized as a cable layout member, higher performance and higher functionality of the gas turbine 1 can be achieved, while suppressing an increase in the dimension of the overall gas turbine 1.

[0041] Although in the above embodiments, the pip unit 51 is provided in the hollow portion 29 of the compressor rotor 11, it may be provided in the turbine rotor 33 instead of or in addition to the compressor rotor 11.

[0042] Although description has been given of preferred embodiments of the present invention with reference to the drawings, the present invention can be added, changed or deleted in various ways within a scope of the present invention. Such addition, change and deletion can be included in the scope of the present invention.

Industrial Applicability

[0043] The present invention is effective in achievement of higher performance and higher functionality of a gas turbine engine while suppressing an increase in a dimension of an overall gas turbine engine.

Reference Sings Lists

[0044]

1 gas turbine engine
2 compressor
5 combustor
7 turbine
11 compressor rotor
23 rotor segments
29 hollow portion (inner space of rotor)
51 pipe unit
53 pipe member
55 flange
85 cable
SP seal air passage
RP cooling medium passage
RA cooling air
SA seal air

Claims

1. A gas turbine engine comprising:

a hollow rotor including a plurality of rotor segments coupled together in a direction of its center axis and defining at least one of a compressor and a turbine; and
a pipe unit inserted into an inner space of the rotor in the center axis direction,
wherein a weight distribution of the pipe unit within an axial transverse section is eccentric with respect to the center axis of the rotor.

2. The gas turbine engine according to Claim 1, wherein the pipe unit includes a pipe member and a flange provided on an outer periphery of the pipe member and fitted to an inner peripheral surface of the rotor.

3. The gas turbine engine according to Claim 2, wherein a weight distribution of the flange within the axial transverse section is eccentric with respect to the center axis of the rotor.

4. The gas turbine engine according to any one of Claims 1 to 3, wherein the pipe unit constitutes a passage of a cooling medium for cooling an interior of the gas turbine engine.

5. The gas turbine engine according to any one of Claims 1 to 3, wherein the pipe unit constitutes a passage of seal air for sealing a bearing supporting the rotor such that the rotor is rotatable.

6. The gas turbine engine according to Claim 4 or 5, wherein the rotor is a compressor rotor, and the cooling medium or the seal air is compressed air extracted from the compressor.

7. The gas turbine engine according to any one of Claims 1 to 3, wherein a cable is extended to inside of the pipe unit.

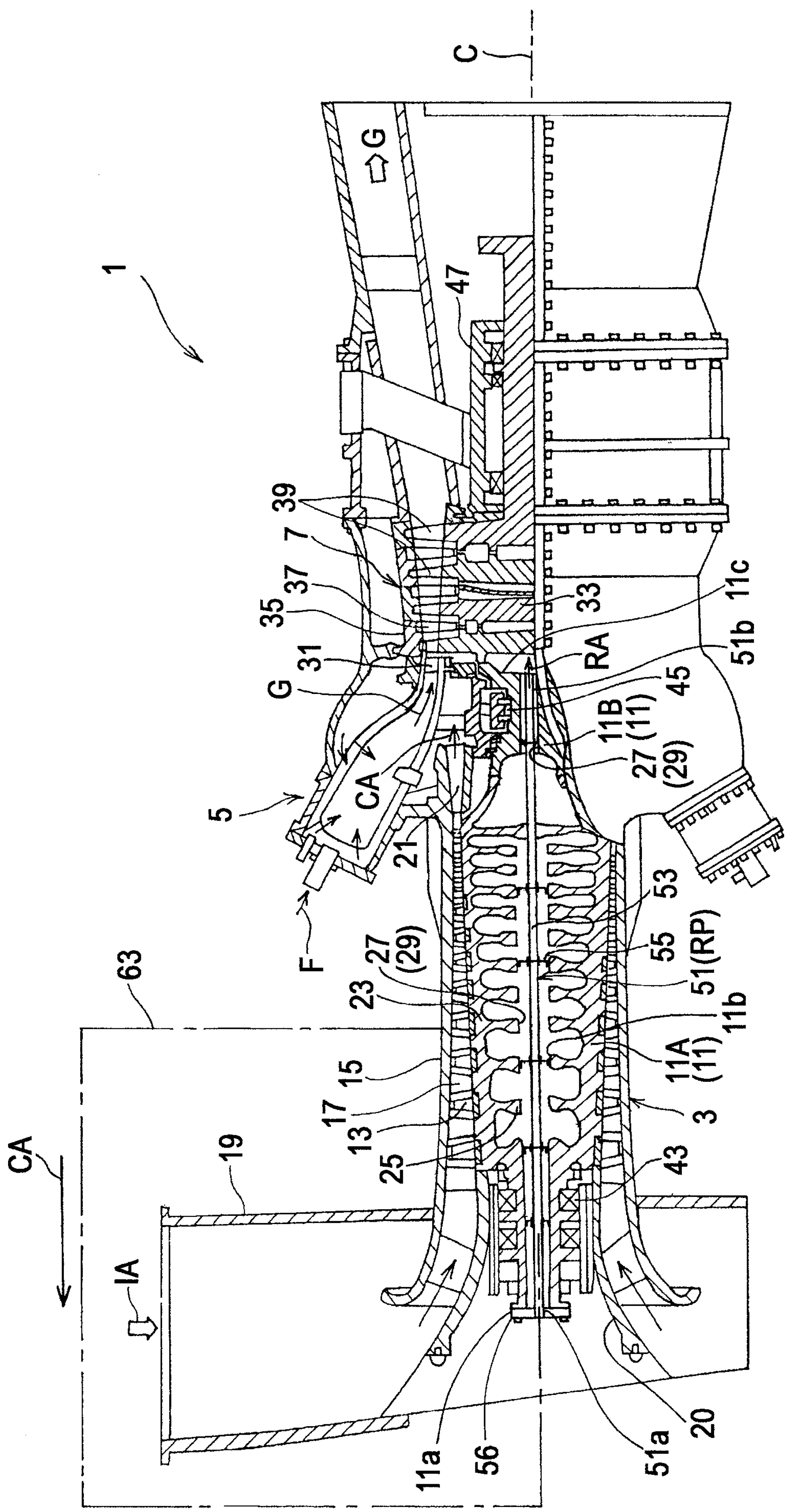
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Fig. 1

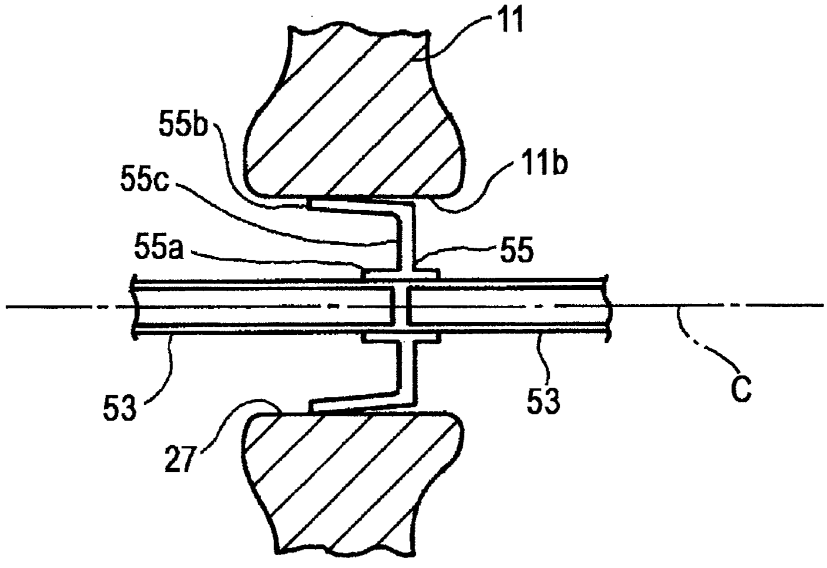

Fig. 2

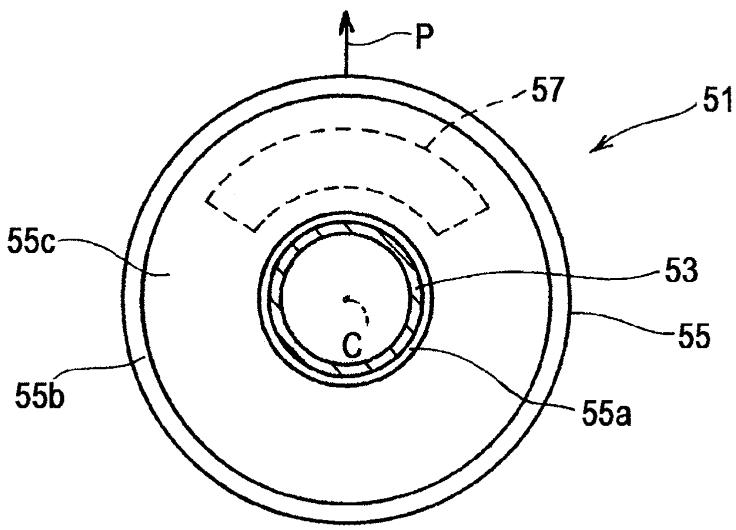

Fig. 3A

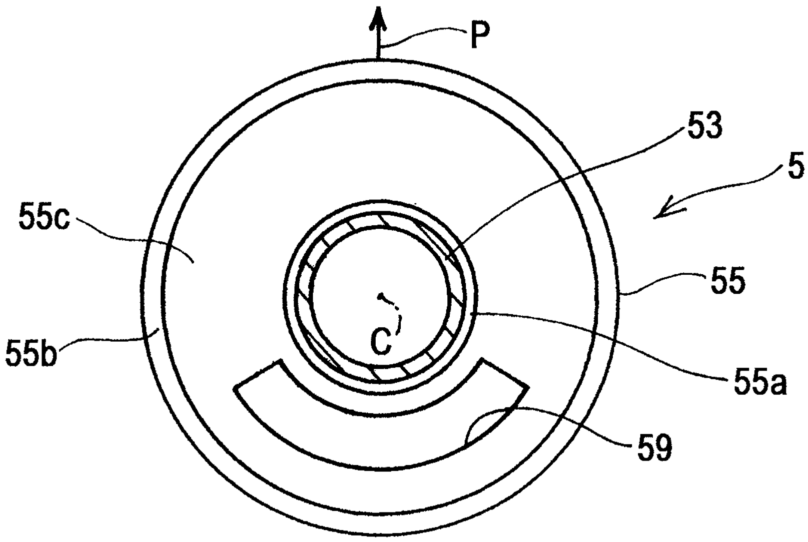

Fig. 3B

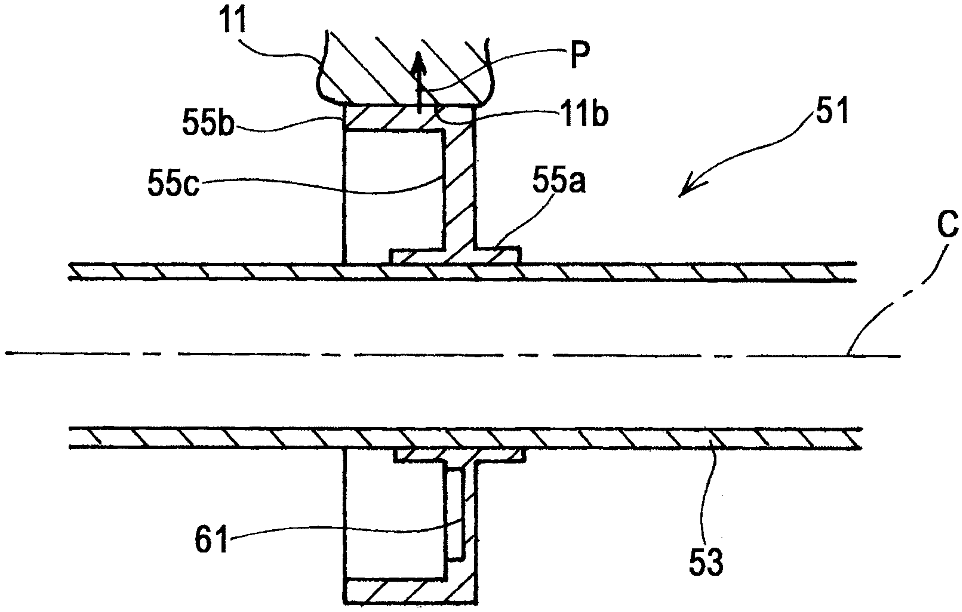

Fig. 3C

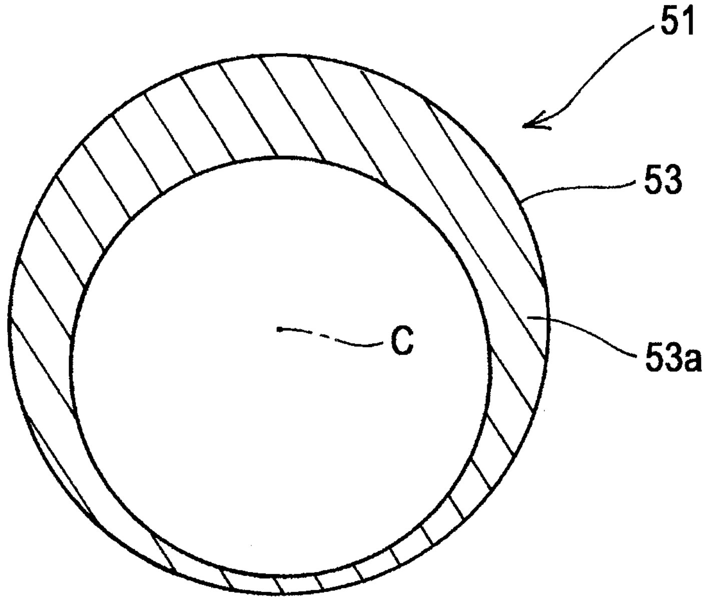

Fig. 4

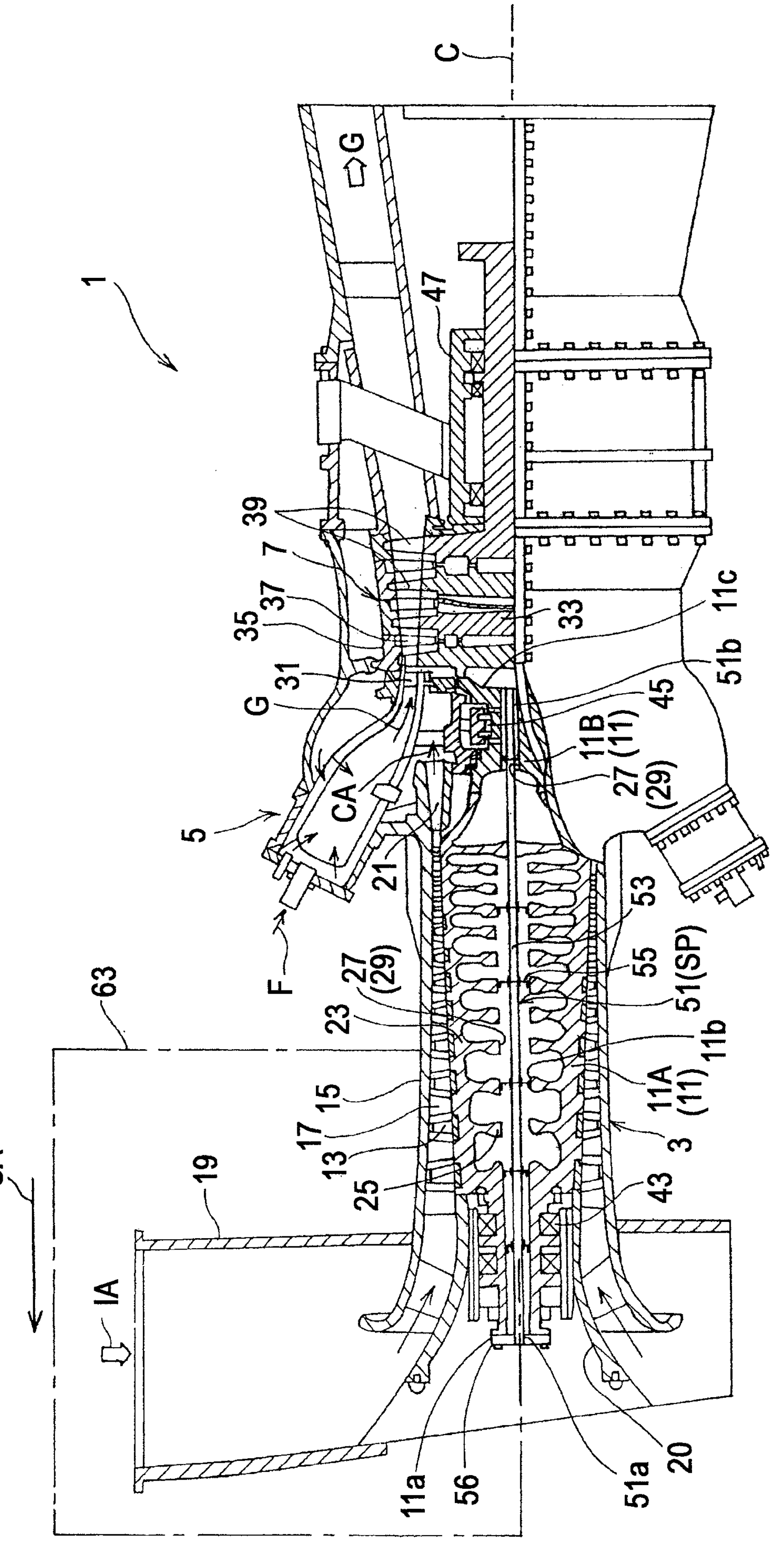
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Fig. 5

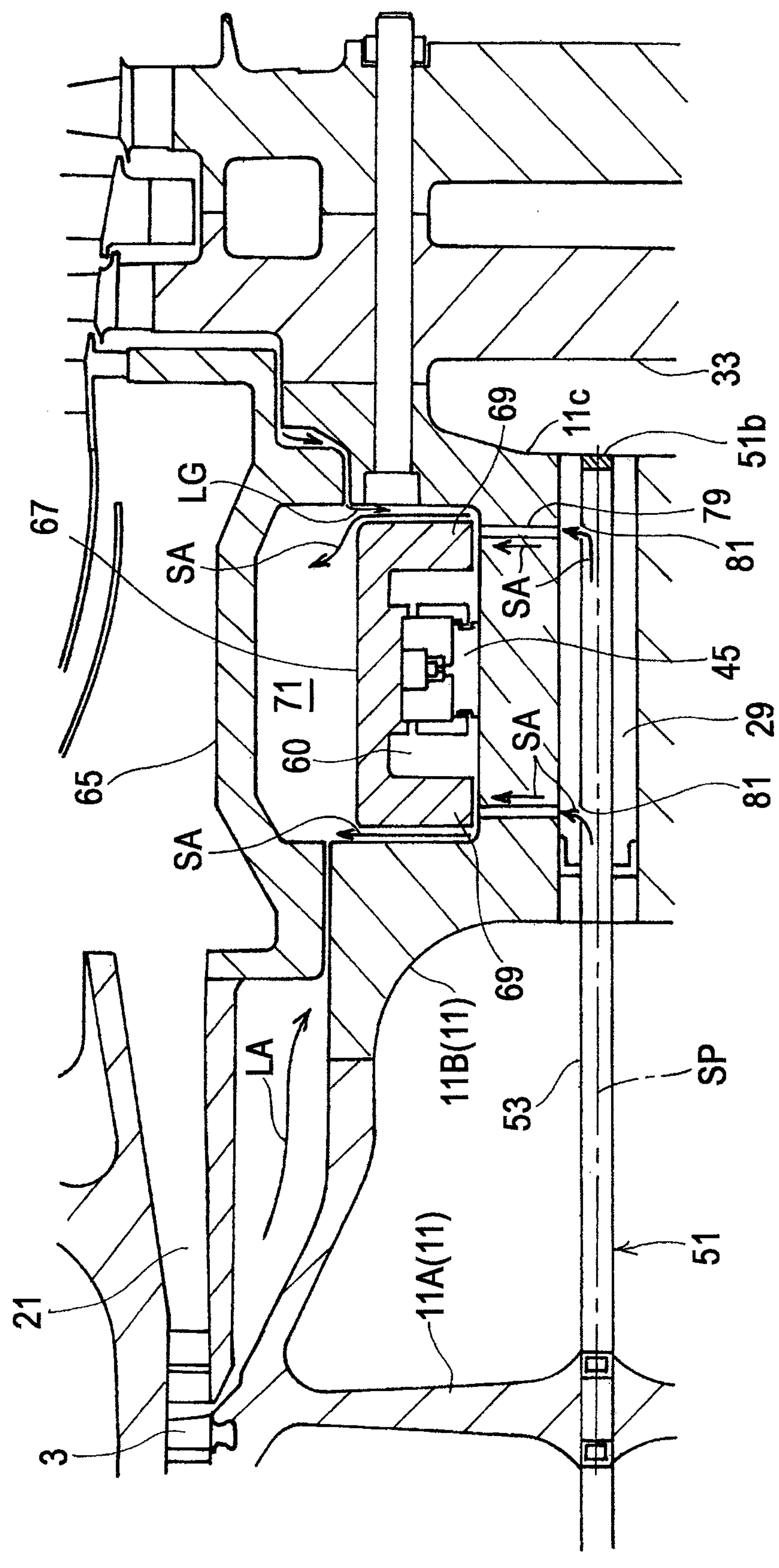

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Fig. 6

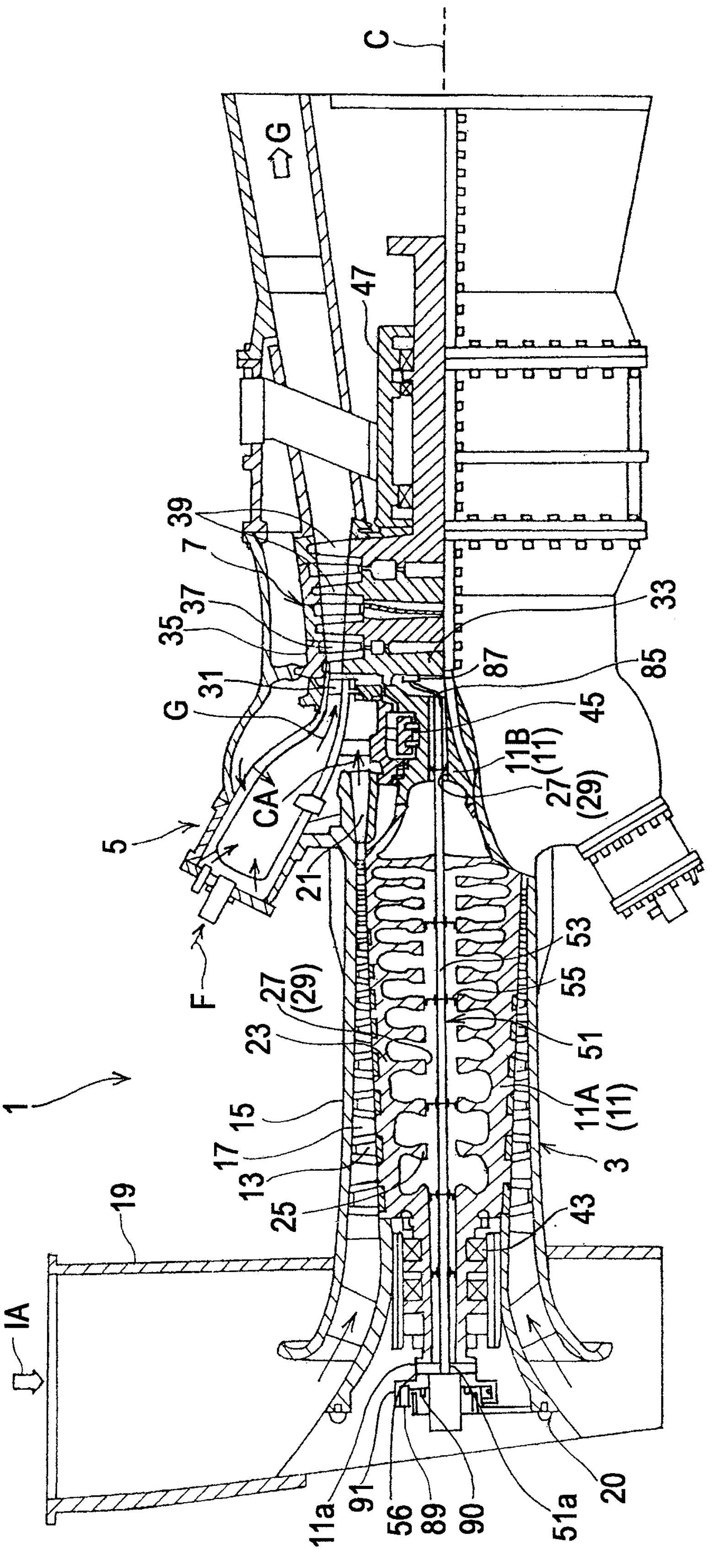
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Fig. 7

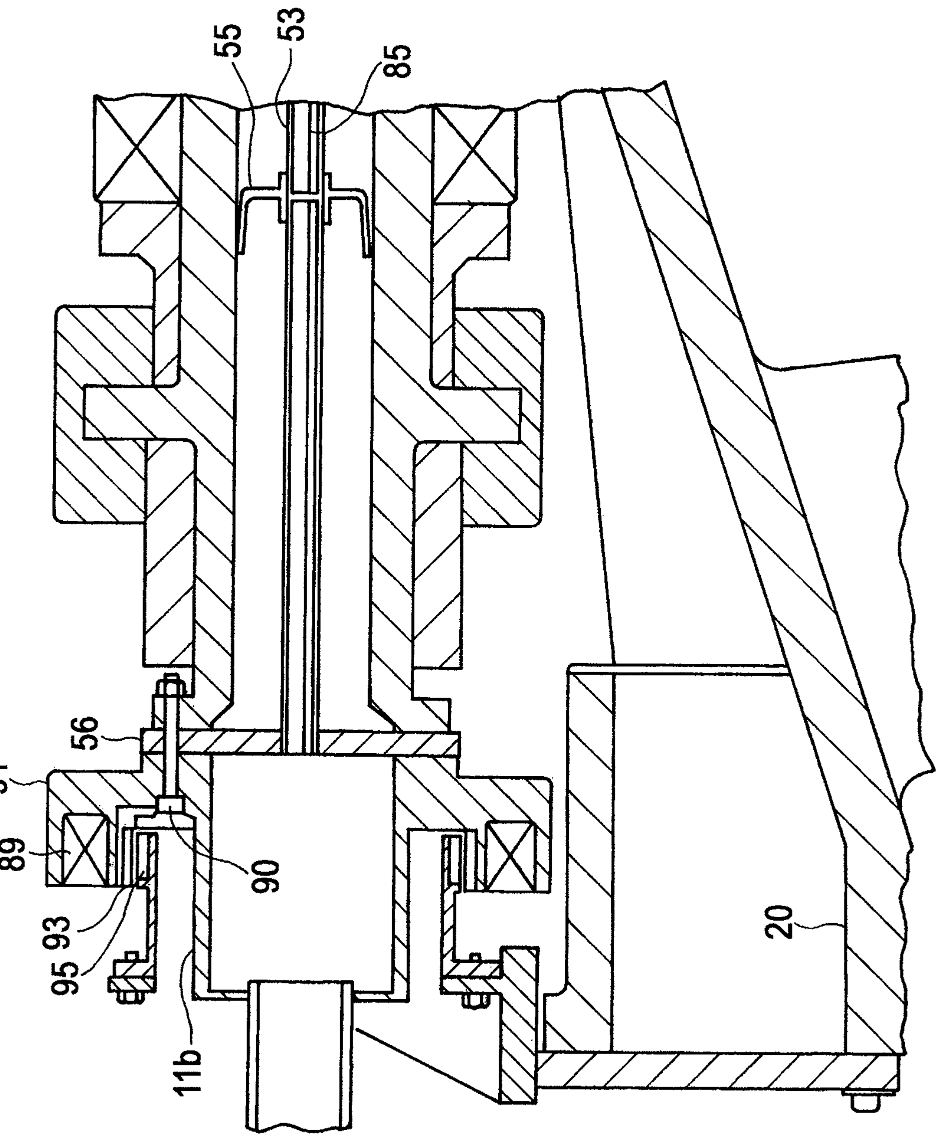

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/000945

A. CLASSIFICATION OF SUBJECT MATTER
F02C7/18(2006.01)i, *F01D5/06*(2006.01)i, *F01D11/04*(2006.01)i, *F01D25/00*(2006.01)i, *F01D25/16*(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)
F02C7/18, F01D5/06, F01D11/04, F01D25/00, F01D25/16

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	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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 10-103004 A (Toshiba Corp.), 21 April 1998 (21.04.1998), fig. 6, 7 & US 6094905 A & KR 10-0259553 B & CN 1178289 A	1,2 4-7 3
Y	JP 10-318187 A (Hitachi, Ltd.), 02 December 1998 (02.12.1998), fig. 1 to 12 (Family: none)	4-6
Y	JP 2001-255132 A (General Electric Co.), 21 September 2001 (21.09.2001), paragraphs [0011], [0012]; fig. 1, 2 & US 6568091 B1 & EP 1128158 A2 & CZ 20003320 A & KR 10-2001-0085239 A	7

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

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Date of the actual completion of the international search 10 May, 2011 (10.05.11)	Date of mailing of the international search report 17 May, 2011 (17.05.11)
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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 11-257012 A (Mitsubishi Heavy Industries, Ltd.), 21 September 1999 (21.09.1999), fig. 1 & US 6224327 B1 & EP 936350 A2 & DE 69935745 D & DE 69935745 T & CA 2262050 A1	1-7
A	JP 11-247604 A (Asea Brown Boveri AG.), 14 September 1999 (14.09.1999), entire text & US 6162018 A & DE 19757945 A1	1-7
A	JP 2005-264788 A (Hitachi, Ltd.), 29 September 2005 (29.09.2005), entire text (Family: none)	1-7

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP HEI11257012 B **[0003]**