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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F02K 1/09

A1

(11) International Publication Number: WO 96/12881

(43) International Publication Date: 2 May 1996 (02.05.96)

(21) International Application Number: PCT/US95/11818

(22) International Filing Date: 15 September 1995 (15.09.95)

(30) Priority Data:
326,621 20 October 1994 (20.10.94) US

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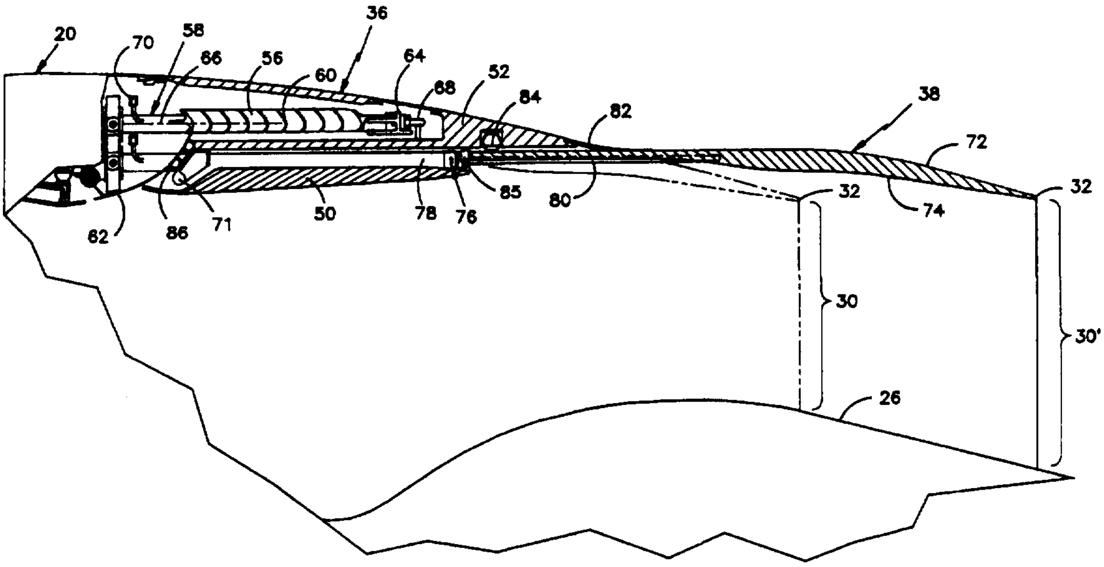
(81) Designated States: JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: VARIABLE AREA FAN EXHAUST NOZZLE



(57) Abstract

A gas turbine engine (10) includes a translating sleeve (38) disposed within a downstream portion of an outer nacelle (20). A variable area fan exhaust nozzle (30) is defined between the trailing edge (32) of the translating sleeve (38) and a conical core cowl (26) disposed radially inward of the outer nacelle (20) and spaced apart therefrom. The translating sleeve (38) translates downstream to cooperate with the decreasing diameter of the core cowl (26) to increase the area of the fan exhaust nozzle (30).

DESCRIPTION

VARIABLE AREA FAN EXHAUST NOZZLE

Technical Field

The present invention relates to a gas turbine engine and, more particularly, to a variable area fan exhaust nozzle therefor.

Background of the Invention

Important performance criteria for modern gas turbine engines include greater thrust, minimization of weight, and reduction in noise levels and fuel consumption. As is well known in the art, a reduction in the fan pressure ratio improves the propulsive efficiency of a gas turbine engine. As the fan pressure ratio is reduced, the mass flow rate through the fan must be increased to maintain the same engine thrust. Longer fan blades increase the mass flow rate. However, reduction of the fan pressure ratio and an increase in the length of the fan blades adversely affect the fan stability. Longer fan blades rotating at lower speeds pump additional air through the fan. At cruise, the additional mass flow at the lower fan pressure ratio contributes to the engine thrust as the air exits through a fan exhaust nozzle disposed downstream of the fan. However, at takeoff, climb, and descent the additional air is restricted through the fan exhaust nozzle and the resulting back pressure on the fan negatively affects the aerodynamic stability of the fan. Thus, fan stability is a limiting factor to low fan pressure ratio engines.

Varying the pitch of the fan blades is one approach to control fan stability. The pitch of the fan blades changes to tailor the amount of airflow passing through the fan during the different modes of operation of the gas turbine engine. During takeoff, climb and descent, the amount of air pumped by the fan blades is reduced, thereby reducing back pressure and avoiding instability conditions.

Another approach to improve performance of the gas turbine engine is described in U.S. Patent No. 5,181,676 to Lair, entitled "Thrust Reverser Integrating A Variable Exhaust Area Nozzle". The patent discloses two clam shells that rotate about a pivot upon actuation to increase the exhaust area of the nozzle. A limitation of the disclosed fan nozzle is that only a small increase in the nozzle area is possible without adversely affecting external or internal aerodynamics. Moreover, the nozzle can suffer undesirable leakage of airflow, thereby reducing the performance of the gas turbine engine. Additionally, since the fan exhaust nozzle functions as a pressure vessel, it is subjected to significant internal pressure that tends to deform each clam shell, since they are supported only at discrete points. The clam shell, as disclosed in the above mentioned patent, must carry a significant weight penalty to control such deformation of the fan exhaust nozzle.

There is still a great need to provide a high performance gas turbine engine having minimized weight, lower noise, and lower fuel consumption levels without jeopardizing other performance characteristics thereof.

Disclosure of the Invention

According to the present invention, a gas turbine engine having a core engine enclosed in a conical core cowl and an outer nacelle with the outer nacelle being disposed radially outward of the core cowl and spaced apart therefrom, includes a translating sleeve disposed in the downstream portion of the outer nacelle to increase the effective area of the fan exhaust nozzle as the translating sleeve translates axially downstream to cooperate with the conical core cowl having a decreasing downstream diameter. The fan exhaust nozzle is defined between the trailing edge of the translating sleeve and the core cowl. The translating sleeve comprises an aerodynamically shaped body and a plurality of actuating means moving the translating sleeve from a fully stowed position axially downstream into a fully deployed position during climb, takeoff, and descent. The translating sleeve is also capable of having a plurality of intermediate deployed positions.

The variable area fan exhaust nozzle allows gas turbine engines to have higher efficiency at cruise without adversely effecting fan stability at other modes of operation. With the translating sleeve in the fully stowed position at cruise, the additional fan airflow improves the propulsive efficiency as the air exits through the fan exhaust nozzle. At takeoff, climb, and descent, the translating sleeve is translated axially downstream into the deployed position so that the effective area of the fan exhaust nozzle, defined between the trailing edge of the axially extended translating sleeve and reduced diameter core cowl, is increased. Therefore, at takeoff, climb, and descent the additional airflow, generated by the fan blades having a lower pressure ratio and a greater mass flow, exits through the increased area of the fan exhaust nozzle without causing sufficient back pressure to stall the fan. Additionally, the present invention improves the fuel consumption at cruise and reduces noise levels at takeoff, climb, and approach. Moreover, the plurality of intermediate deployed positions of the translating sleeve result in a gradual and continuous variation of area of the fan exhaust nozzle, allowing further optimization of performance of the gas turbine engine by improving weight of the overall engine and fuel consumption.

One feature of the present invention is that the translating sleeve comprises two semi-cylinders mating with each other to provide a continuous inner surface of the nozzle to withstand internal pressure and to minimize the leakage of airflow. A major advantage of the present invention is that the translating sleeve is relatively simple structurally and is able to withstand "hoop" loading with relatively light weight structure.

The foregoing and other objects and advantages of the present invention become more apparent in light of the following detailed description of the exemplary embodiments thereof, as illustrated in the accompanying drawings.

Brief Description of the Drawings

FIG. 1 is a simplified, cross sectioned elevation of a gas turbine engine and a nacelle with a thrust reverser and a translating sleeve, according to the present invention;

FIG. 2 is an enlarged, sectioned elevation of the thrust reverser and the translating sleeve of FIG. 1 at cruise with the thrust reverser and translating sleeve being depicted in a stowed position;

FIG. 3 is a sectioned elevation of the thrust reverser and the translating sleeve of FIG. 2, at takeoff, climb, and descent with the translating sleeve being depicted in deployed position;

FIG. 4 is a sectioned elevation of the thrust reverser and the translating sleeve of FIG. 3 at reverse with both the thrust reverser and the translating sleeve being depicted in deployed position; and

FIG. 5 is a diagrammatic, cross sectioned elevation of the thrust reverser and the translating sleeve of FIG. 4, taken along line 5-5.

Best Mode for Carrying Out the Invention

Referring to FIG. 1, a gas turbine engine 10 having a core engine 12 with a fan 14 disposed about a center longitudinal axis 16 includes an annular nacelle 18 encasing the core engine 12. The annular nacelle 18 comprises an outer nacelle 20 having an upstream portion 22 and a downstream portion 24 and a conical core cowl 26 disposed radially inward from the outer nacelle 20 and spaced apart therefrom. The outer nacelle 20 and the core cowl 26 define an annular flow path 28 therebetween. A fan exhaust nozzle 30 is defined between a trailing edge 32 of the outer nacelle 20 and the core cowl 26.

Referring to FIGS. 2-4, the downstream portion 24 of the outer nacelle 20 includes a thrust reverser mechanism 36 and a variable area fan exhaust nozzle translating sleeve 38. The thrust reverser mechanism 36 is of a conventional type, having a thrust reverser blocker door 50 and a thrust reverser movable body 52 with a recess 54 to accommodate a plurality of turning vanes 56 and a plurality of thrust reverser actuators 58 (superseded in FIG. 2) therein. The turning vanes 56, that include a plurality of guide vanes 60, are secured onto a torque box 62 on the upstream end thereof and a support ring 64 on the downstream end thereof. The thrust reverser actuators 58 are hydraulic actuators of the conventional type, having a cylinder 66 and a moveable rod 68, wherein the cylinder is secured onto the torque box 62 and the rod 68 is secured onto an inner surface of the recess 54. Hydraulic pressure to the actuators is provided through tubing 70. The thrust reverser blocker door 50 is disposed radially inward of the thrust reverser body 52 and is in a substantially parallel relationship to the longitudinal axis 16 when in a stowed position, as shown in FIGs. 1 and 2. The thrust reverser blocker door 50 pivots about a pivot point 71 into a deployed position, as shown in FIG. 4.

The fan exhaust nozzle translating sleeve 38, having an aerodynamically shaped outer surface 72 and inner surface 74, is disposed radially inward of the thrust reverser 36 and radially outward of the blocker door 50 and extends downstream of the thrust reverser 36. A plurality of translating sleeve actuators 76 provide axial translation to the translating sleeve 38. Each actuator 76 is of a hydraulic type, having a cylinder 78 and a moveable rod 80, with the cylinder 78 being secured onto the torque box 62 and the rod 80 being secured onto the translating sleeve 38. An aerodynamic flap seal 82 is fixedly attached to the most downstream portion of the thrust reverser 36 to bridge the gap between the thrust reverser 36 and the translating sleeve 38 to ensure an aerodynamically smooth exterior surface of the outer nacelle 20. An inflatable seal 84 is disposed between the translating sleeve 38 and the thrust reverser 36 to reduce air leakage therebetween during translation. Alternatively, a lip seal or any other type of a seal may be used to prevent air leakage. A translating sleeve bumper seal 85 is disposed on a leading edge of the translating sleeve 38 and bears against the pivot point 71, when the translating sleeve 38 is in a fully stowed position. A thrust reverser bumper seal 86 is disposed on the leading edge of the inner wall of the thrust reverser body 52 and bears against the torque box 62 when the thrust reverser 36 is in the fully stowed position to reduce air leakage.

Referring to FIG. 5, the thrust reverser body 52 and the translating sleeve 38 each comprises two semi-cylinders 88, 89 and 90, 91, respectively. Each semi-cylinder 90, 91 of the translating sleeve 38 includes longitudinal edges 92-93, 94-95, respectively. Each longitudinal edge 92-95 has a T-slider 96 attached thereto. The T-sliders 96 of the longitudinal edges 92, 94 slidingly engage tracks 97 of a hinge mechanism 98. The hinge mechanism 98 includes a mounting hinge 99 securing the hinge mechanism 98 onto a pylon (not shown), which is attached to the wing of the airplane (not shown). The T-sliders 96 of the longitudinal edges 92-95 of the translating sleeve 38 slidingly engage tracks 97 of a latch mechanism 100, which is disposed substantially diagonally across from the hinge mechanism 98. The semi-cylinders 90, 91 of the translating sleeve 38 and the latch and hinge mechanisms 100, 98 form a substantially continuous annulus with the substantially continuous surface 74. The thrust reverser 36 has a mounting structure analogous to that of the translating sleeve 38. T-sliders 96 of longitudinal edges 101-104 of the semi-cylinders 88, 89 of the thrust reverser body 52 slidingly engage the tracks 97 of the hinge and latch mechanisms 98, 100. The latch mechanism 100 can be opened to allow the two sets of semi-cylinders 88-89, 90-91 of the thrust reverser 36 and of the translating sleeve 38 to pivot about the hinge mechanism 98 to allow access to the core engine 12 disposed therein. O-ring seals (not shown) are disposed at the ends of the tracks 97 to prevent air leakage between the tracks 97 and the T-sliders 96.

In cruise mode, shown in FIGS. 1 and 2, both the thrust reverser 36 and the fan exhaust nozzle translating sleeve 38 are in a fully stowed position with the movable rods 68, 80 of the thrust reverser actuators 58 and of the translating sleeve actuators 76 in their retracted positions. As shown in FIG. 5, there are six thrust reverser actuators 76 and six translating sleeve actuators 58.

At takeoff, climb, and descent, shown in FIG. 3, the translating sleeve 38 is fully deployed. The hydraulic pressure activates the plurality of translating sleeve actuators 76 so that the moveable rods 80 extend axially downstream, thereby transmitting axial, downstream movement to the translating sleeve 38. The sliding downstream movement is effectuated as the T-sliders 96 disposed along the longitudinal edges 92-95 of the semi-cylinders 90, 91 of the translating sleeve 38 slidingly engage the tracks 97 of the hinge and latch mechanisms 98, 100. As the translating sleeve 38 is translated downstream, the annular area of the effective fan exhaust nozzle 30' defined by the trailing edge 32 of the translating sleeve 38 and the core cowl 26 is increased. The effective increase in the annular area of the fan nozzle is gained due to the decreasing downstream diameter of the conical core cowl 26. The greater area fan nozzle 30' becomes the controlling area for the exiting airflow 28 at takeoff, climb, and descent. The aerodynamically shaped inner surface 74 of the translating sleeve 38 insures that the airflow is not choked upstream of the fan exhaust nozzle 30'. A number of intermediate deployed positions between the fully stowed position and fully deployed position for the translating sleeve are possible with the hydraulic actuators being activated gradually.

After touch down, the thrust reverser 36 may be activated to provide reverse thrust to the gas turbine engine 10. For the thrust reverser 36 to be activated and effective, the translating sleeve 38 must also be activated to expose the turning vanes 56 to the airflow 28. The translating sleeve 38 is activated and translates downstream in the same manner as described above. The thrust reverser 36 is moved axially downstream when the hydraulic pressure builds up in the thrust reverser cylinders 66 and extends the moveable rods 68 axially downstream. The thrust reverser 36 then slidingly moves downstream as the thrust reverser T-slides 96 slide downstream in the tracks 97. The reverser door 50 pivots radially inward to block the air flow path 28 from exiting through the fan exhaust nozzle 30', thereby redirecting the airflow to pass through the guide vanes 60.

The gas turbine engines that employ the present invention can achieve higher propulsive efficiency with a lower pressure ratio and higher mass flow without sacrificing engine thrust and without fan stability problems. At cruise, as the translating sleeve is in the fully stowed position, the gas turbine engines with lower pressure ratios enjoy higher thrust, reduced noise levels and improved fuel consumption. At takeoff, climb, and approach, as the translating sleeve is in one of the deployed positions, the increased area of the fan exhaust nozzle 30' allows the additional air flow generated by the fan to exit the engine 10 without causing excessive back pressure on the fan blades and thus without stalling the fan 14. Moreover, gradually and continuously varying area of the fan exhaust nozzle allows further optimization of the performance by reducing the overall weight of the gas turbine engine and improving fuel consumption.

Furthermore, the combination of the lower fan pressure ratio and the higher fan mass flow reduces noise levels at approach, takeoff and climb. The noise reduction is a result of two factors. First, the fan rotating at lower speeds thereby producing less noise. Second, the extended downstream translating sleeve affords an additional attenuation path that reduces noise levels. Moreover, the combination of the lower fan pressure ratio and the higher fan mass flow improves fuel consumption at cruise.

The variable area fan exhaust nozzle having the translating sleeve 38 of the present invention allows an increase in the area of the nozzle 30' in excess of 40%. The translating sleeve 38 achieves a significant increase in the area of the nozzle 30' without a significant weight penalty to the gas turbine engine 10. Furthermore, the two semi-cylinders 90, 91 of the translating sleeve 38 form a continuous inner surface 74 of the fan exhaust nozzle. The continuous surface 74 allows the nozzle to withstand the internal pressure of the airflow without excessive weight and to avoid air leakage.

As an alternate embodiment, this invention can be used with a thrust reverser having translating turning vanes, rather than stationary turning vanes 56, as described in the preferred embodiment.

We claim:

1. A gas turbine engine having a core engine enclosed in a core cowl and an outer nacelle disposed about a longitudinal axis, said outer nacelle being disposed radially outward of said core cowl and spaced apart therefrom, said outer nacelle having an upstream portion and a downstream portion, said core cowl having a generally conical shape with a decreasing downstream diameter, said gas turbine engine characterized by:

a translating sleeve having a fully stowed position, a fully deployed position and a plurality of intermediate deployed positions, a fan exhaust nozzle being defined between a trailing edge of said translating sleeve and said core cowl, said translating sleeve translating axially downstream to cooperate with said decreasing downstream diameter of said core cowl to vary area of said fan exhaust nozzle; and

a plurality of actuating means providing translating movement to said translating sleeve.

2. The gas turbine engine according to claim 1 further characterized by said translating sleeve having a plurality of semi-cylinders engaged with each other along longitudinal edges thereof to form a continuous surface of said fan exhaust nozzle.

3. The gas turbine engine according to claim 2 further characterized by said semi-cylinders of said translating sleeve having sliding means disposed on said longitudinal edges thereof to slidingly engage mating tracks disposed on a latch mechanism and a hinge mechanism to provide sliding movement to said translating sleeve.

4. The gas turbine engine according to claim 1 further characterized by said plurality of actuating means being hydraulically driven.

5. The gas turbine engine according to claim 4 further characterized by each said actuating means having a cylinder secured onto said gas turbine engine and a moveable rod secured onto said translating sleeve, said rod being retracted into said cylinder in said fully stowed position and extended in said fully deployed position.

6. A gas turbine engine having a core engine enclosed in a core cowl and an outer nacelle, said outer nacelle being disposed radially outward of said core cowl and spaced apart therefrom, said outer nacelle having an upstream portion and a downstream portion, said core cowl having a generally conical shape with a decreasing downstream diameter, said outer nacelle having a thrust reverser disposed within said downstream portion thereof, said thrust reverser having a stowed position, said thrust reverser moving axially downstream into a deployed position, said gas turbine engine characterized by:

a translating sleeve slidingly mounted downstream of said thrust reverser having a fully stowed position, a fully deployed position and a plurality of intermediate deployed positions, a fan exhaust nozzle being defined between a trailing edge of said translating sleeve and said core cowl, said translating sleeve translating axially downstream to cooperate with said decreasing downstream diameter of said core cowl to vary area of said fan exhaust nozzle; and

a plurality of actuating means providing translating movement to said translating sleeve between said fully stowed position and said fully deployed position.

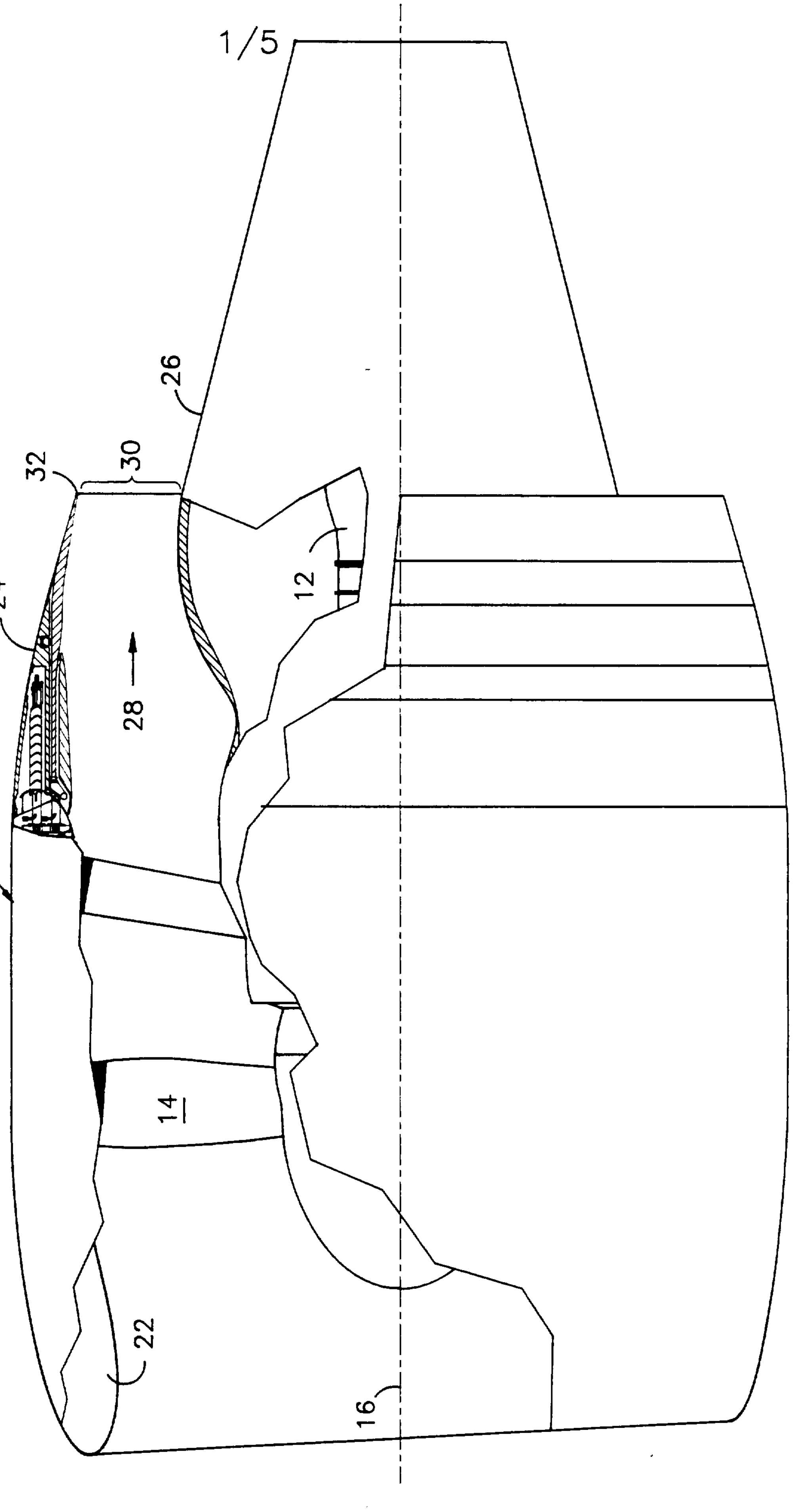


fig. 1

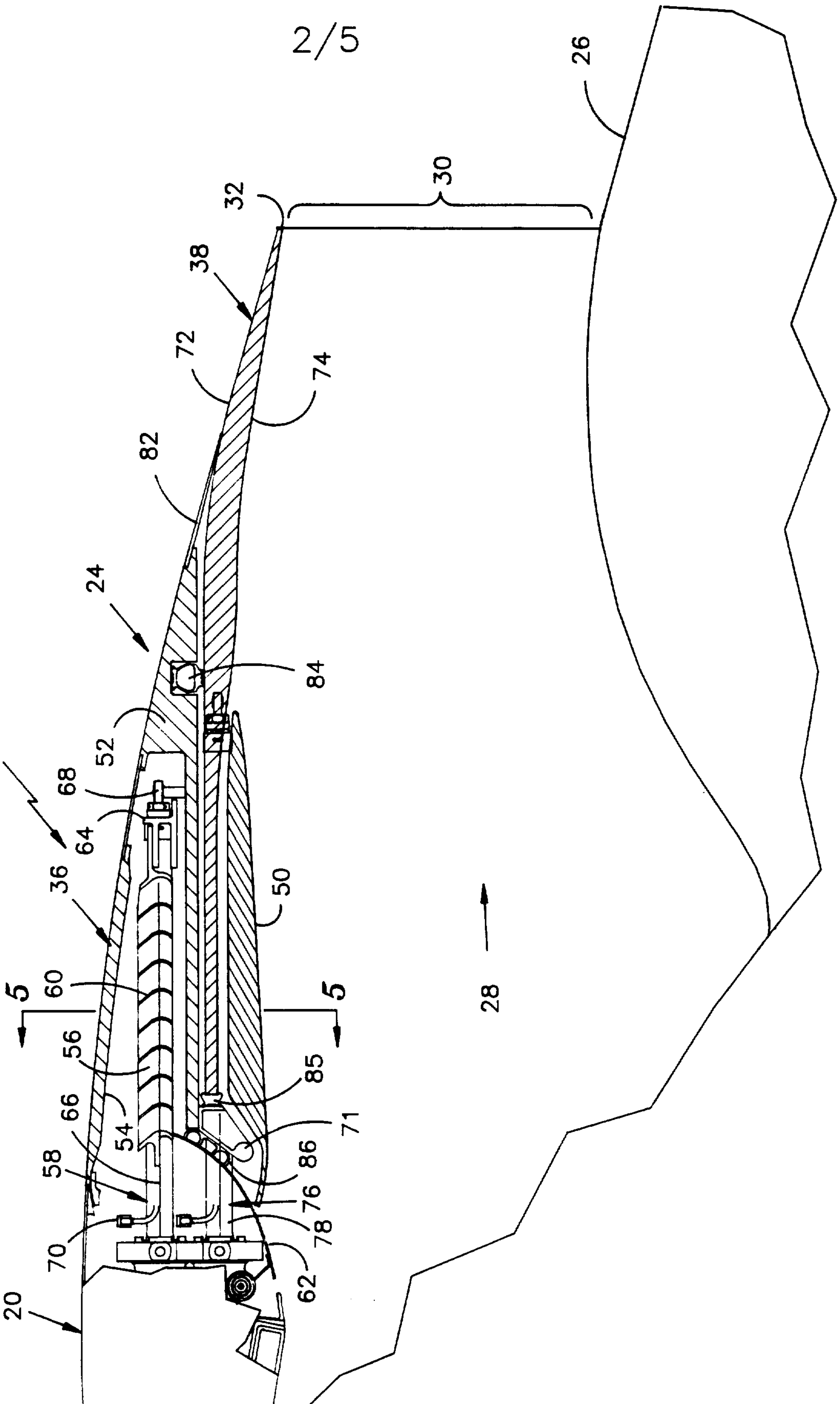

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fig.2

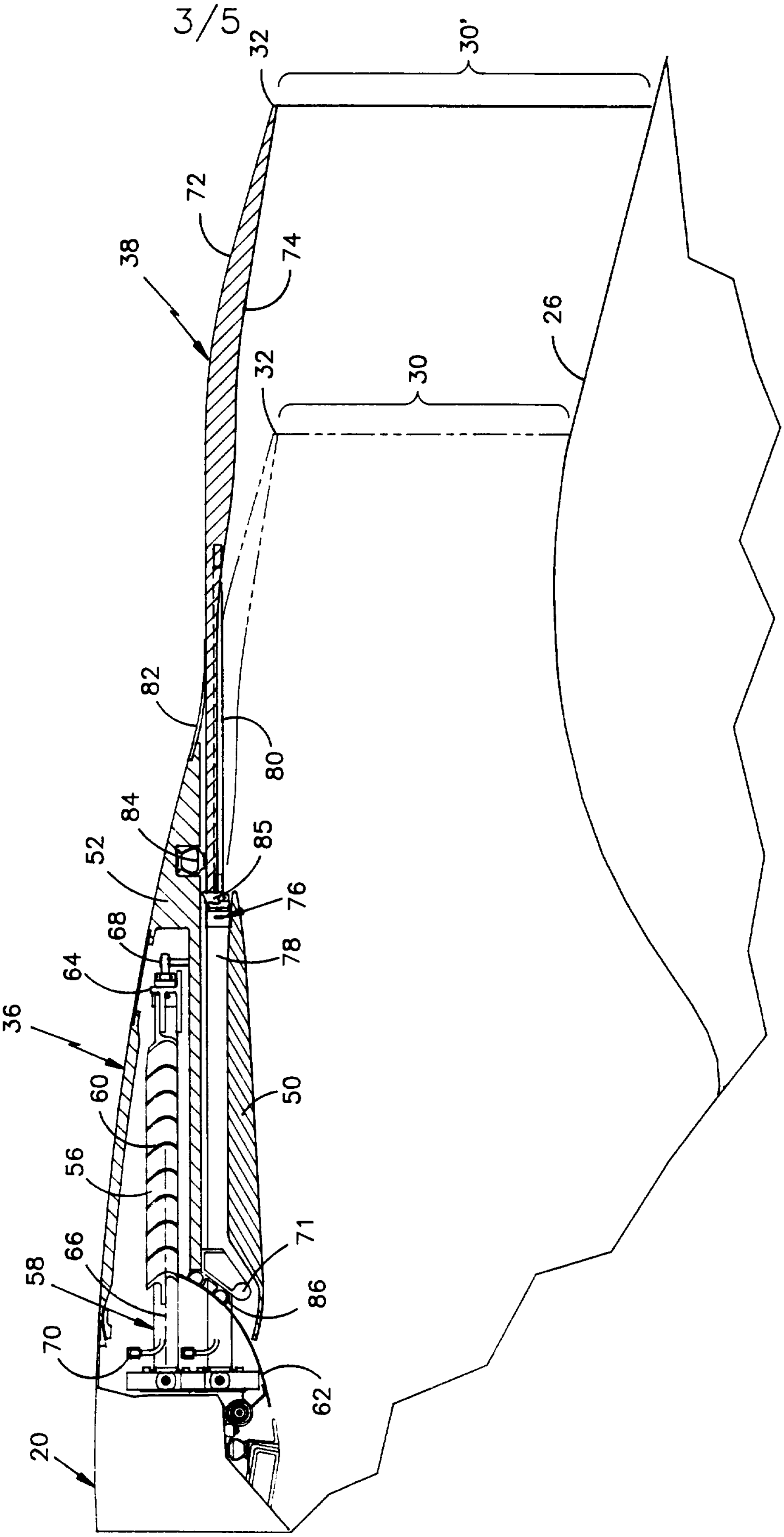

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fig. 3

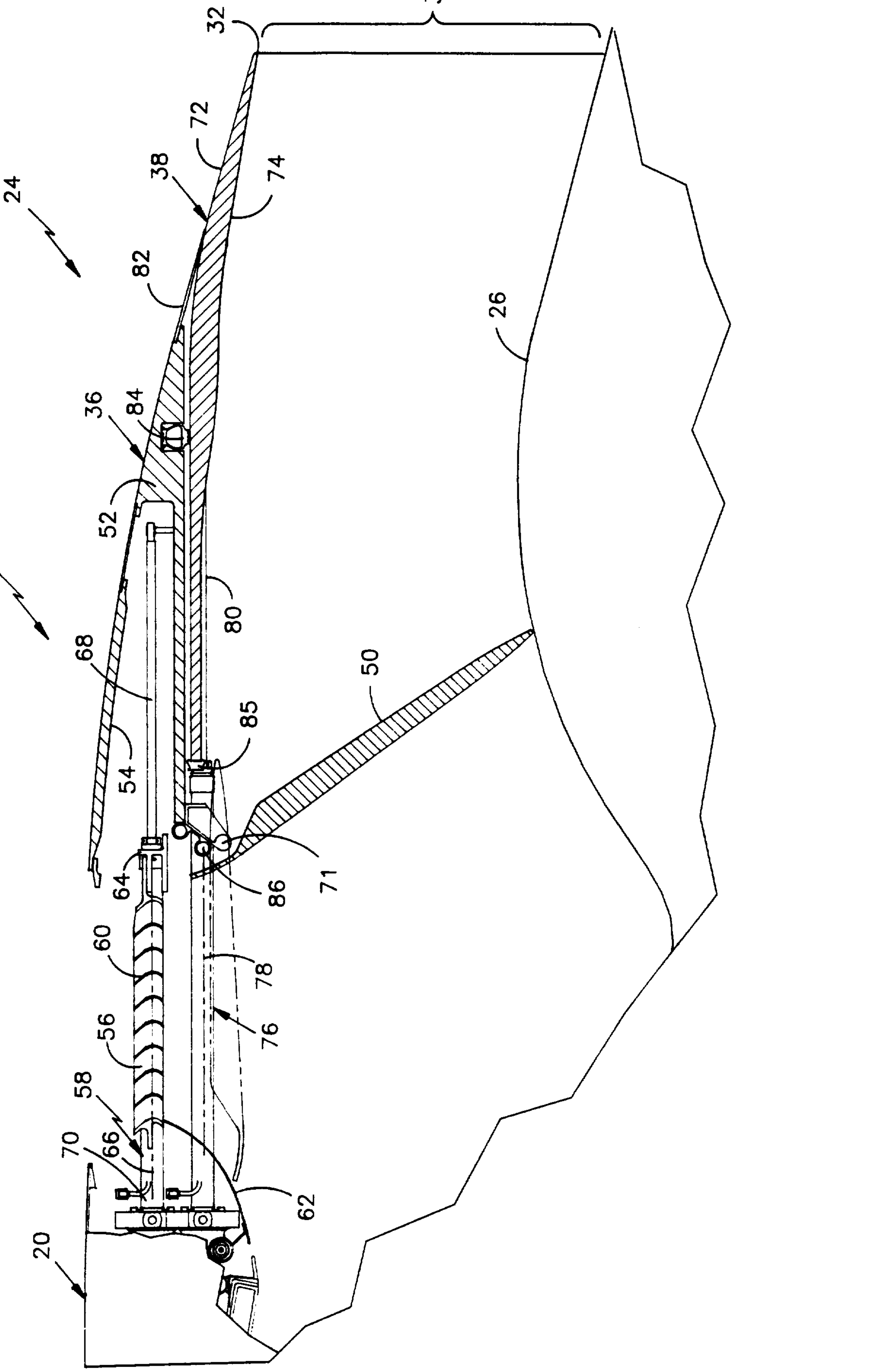
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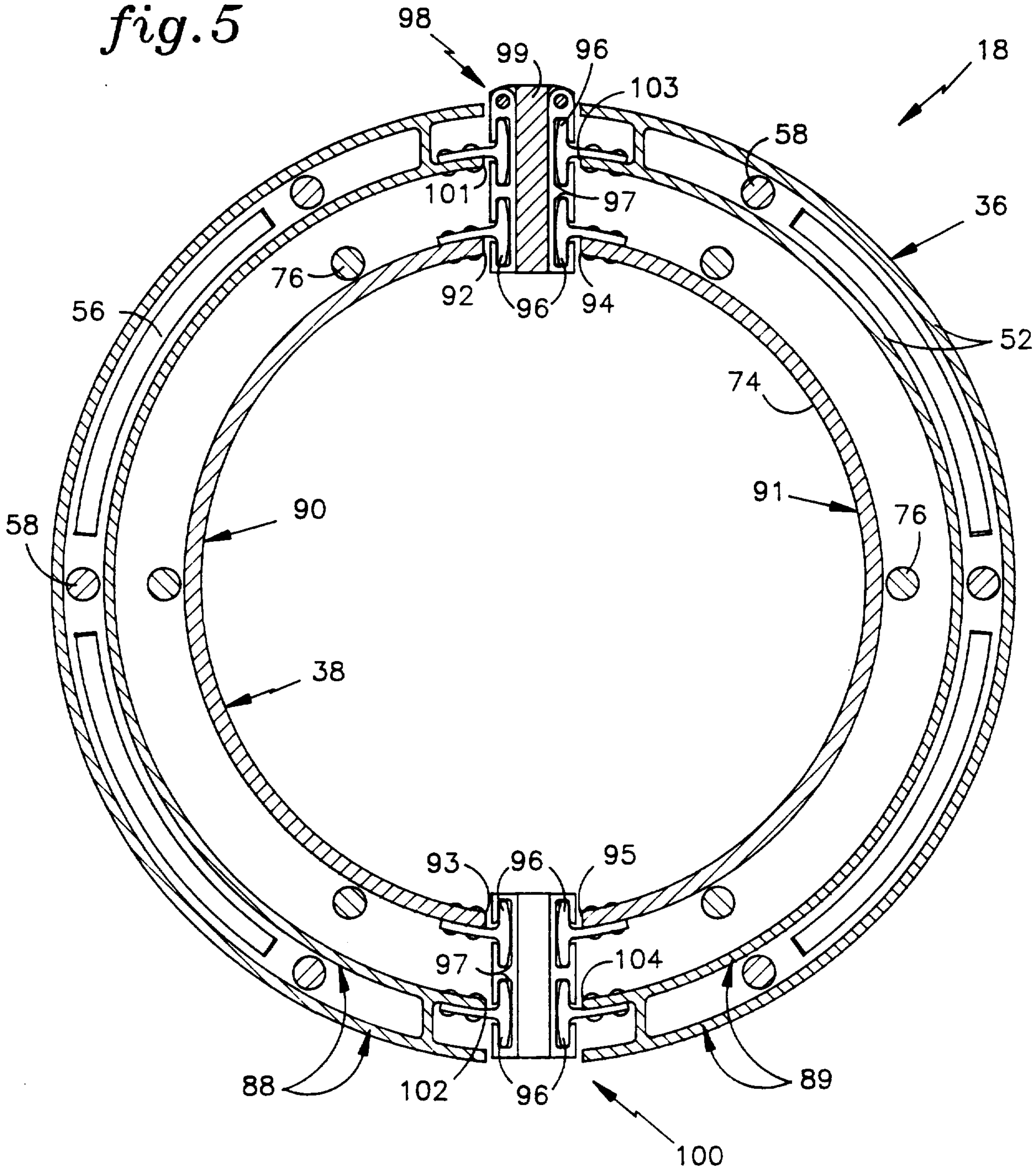
fig. 4

fig.5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INTERNATIONAL SEARCH REPORT

Inte. .onal Application No
PCT/US 95/11818

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F02K1/09

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)
IPC 6 F02K B64C

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

Electronic data base consulted during the international search (name of data base and, where practical, 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	US,A,3 797 785 (BAERRENSEN ET AL.) 19 March 1974 see the whole document	1-6
X	US,A,3 779 010 (CHAMAY ET AL.) 18 December 1973 see figures 1-3,5	1-6
X	US,A,4 802 629 (G.W.KLEES) 7 February 1989 see figures 3,7,8	1-6
A	EP,A,0 191 204 (THE BOEING COMPANY) 20 August 1986 see abstract	2

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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1

Date of the actual completion of the international search	Date of mailing of the international search report
5 February 1996	14.02.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Argentini, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 95/11818

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-3797785	19-03-74	NONE	
US-A-3779010	18-12-73	NONE	
US-A-4802629	07-02-89	NONE	
EP-A-191204	20-08-86	US-A- 4541673	17-09-85