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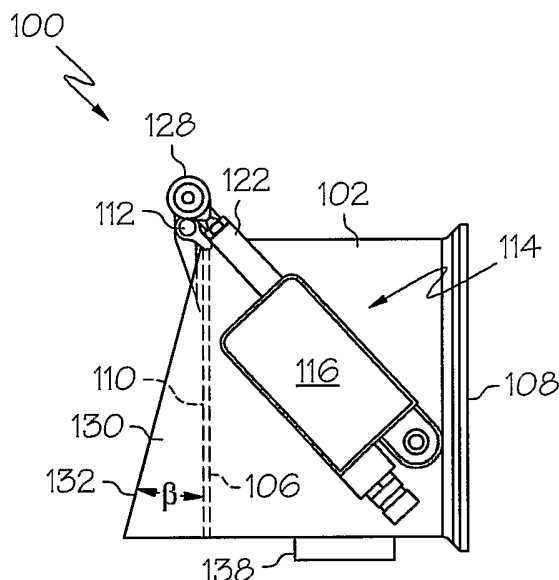
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(54) Title: CABIN PRESSURE OUTFLOW CONTROL VALVE HAVING NON-LINEAR FLOW CONTROL CHARACTERISTICS



(57) Abstract: An aircraft cabin pressure outflow control valve that includes a rotationally mounted valve gate (110) and one or more flow influencing walls (130) adjacent to or part of to the valve body (102). Each wall has a distal edge (132) formed at a wall angle relative to one of the valve flow ports (106, 108), and an inner surface (134) that surrounds the valve gate (110) when the valve is at or near its closed position. With this configuration, the effective flow area of the flow port varies substantially non-linearly over a range of valve positions.

CABIN PRESSURE OUTFLOW CONTROL VALVE HAVING NON-LINEAR FLOW CONTROL CHARACTERISTICS

FIELD OF THE INVENTION

5 **[0001]** The present invention relates to an aircraft cabin pressure outflow control valve and, more particularly, to an aircraft cabin pressure outflow control valve that exhibits non-linear flow control characteristics in at least certain valve positions.

BACKGROUND OF THE INVENTION

10 **[0002]** For a given airspeed, an aircraft may consume less fuel at a higher altitude than it does at a lower altitude. In other words, an aircraft may be more efficient in flight at higher altitudes as compared to lower altitudes. Moreover, bad weather and turbulence can sometimes be avoided by flying above such weather or turbulence. Thus, because of these and other potential advantages, many aircraft are designed to
15 fly at relatively high altitudes.

[0003] As the altitude of an aircraft increases, the ambient pressure outside of the aircraft decreases and, unless otherwise controlled, excessive amounts of air could leak out of the aircraft cabin causing it to decompress to an undesirably low pressure. If the pressure in the aircraft cabin is too low, the aircraft passengers may suffer
20 hypoxia, which is a deficiency of oxygen concentration in human tissue. The response to hypoxia may vary from person to person, but its effects generally include drowsiness, mental fatigue, headache, nausea, euphoria, and diminished mental capacity.

[0004] Aircraft cabin pressure is often referred to in terms of "cabin pressure
25 altitude," which refers to the normal atmospheric pressure existing at a certain altitude. Studies have shown that the symptoms of hypoxia may become noticeable when the cabin pressure altitude is above the equivalent of the atmospheric pressure one would experience outside at 8,000 feet. Thus, many aircraft are equipped with a cabin pressure control system to, among other things, maintain the cabin pressure
30 altitude to within a relatively comfortable range (e.g., at or below approximately 8,000 feet) and allow gradual changes in the cabin pressure altitude to minimize passenger discomfort.

[0005] To maintain aircraft cabin altitude within a relatively comfortable range, cabin pressure control systems may be equipped with one or more outflow valves. An

outflow valve can assist in controlling cabin pressure by regulating air flow out of the cabin. One particular type of outflow valve that may be used has a rotatable flapper or gate as the control element to regulate the flow of air out of the cabin. The flapper is coupled to a shaft that is rotationally mounted to the outflow valve body adjacent to the cabin side flow port. An actuator, which is coupled to the shaft, positions the flapper element in response to commands from a controller to thereby regulate the air flow out of the cabin.

[0006] Although the above-described type of outflow valve is believed to be generally safe and reliable, is fairly simple to design and construct, and thus fairly inexpensive, under certain circumstances it may exhibit certain drawbacks. One particular drawback relates to flow control resolution around the closed position. In particular, when the flapper is positioned at or near its closed position, small changes in valve position can result in relatively large changes in flow area. As a result of this particular characteristic, flow control resolution difficulties may be exhibited around the closed position. This is potentially significant, since the outflow valve is operated with the flapper in or near its closed position for most operational conditions.

[0007] Hence, there is a need for an outflow valve that is fairly simple to design and construct, and that is relatively inexpensive, and that additionally overcomes the above-noted drawback. Namely, a relatively simple, inexpensive valve that does not exhibit relatively large changes in flow area with relatively small changes in position when the valve is at or near its closed position, and/or does not exhibit control difficulties around the closed position. The present invention addresses these needs.

SUMMARY OF THE INVENTION

[0008] The present invention provides a relatively simple, inexpensive aircraft cabin pressure control valve that includes a gate as its flow control element, which does not exhibit relatively large changes in flow area with relatively small changes in position when the gate is at or near its closed position. As a result, the valve also exhibits good flow control resolution around the closed position.

[0009] In one embodiment, and by way of example only, an aircraft cabin pressure outflow control valve includes a valve body, a valve gate, and one or more walls. The valve body is adapted to mount in the fuselage of an aircraft and has at least a first flow port, a second flow port, and a flow passage therebetween. The valve gate is rotationally mounted on the valve body proximate the first flow port, and

is rotatable between a plurality of valve angles relative to the first flow port to thereby control an effective flow area therethrough. The valve gate is in a closed position when the valve angle is zero degrees. Each of the one or more walls has at least a distal edge, an inner surface, and an outer surface. Each wall inner surface surrounds at least a portion of the valve gate at least when the valve angle is zero degrees. Each wall distal edge is formed at a wall angle relative to the first flow port. The effective flow area through the first flow port varies substantially non-linearly with valve angle for valve angles from zero degrees up to a predetermined number of degrees.

5 [0010] In another exemplary embodiment, an aircraft cabin pressure outflow control valve includes a valve body, a valve gate, a controller, a valve actuator, and one or more walls. The valve body is adapted to mount on the fuselage of an aircraft and has at least a first flow port, a second flow port, and a flow passage therebetween. The valve gate is rotationally mounted on the valve body proximate the first flow port, and is rotatable between a plurality of valve angles relative to the first flow port to thereby control an effective flow area therethrough. The valve gate is in a closed position when the valve angle is zero degrees. The controller circuit is mounted on the valve body and is operable, in response to one or more aircraft cabin pressure signals, to supply a valve actuation signal. The valve actuator is mounted on the valve body and is operable, in response to the valve actuation signals, to position the valve gate at a valve angle. Each of the one or more walls has at least a distal edge, an inner surface, and an outer surface. Each wall inner surface surrounds at least a portion of the valve gate at least when the valve angle is zero degrees. Each wall distal edge is formed at a wall angle relative to the first flow port. The effective flow area through the first flow port varies substantially non-linearly with valve angle for valve angles from zero degrees up to a predetermined number of degrees.

15 20 25 30 [0011] In still another exemplary embodiment, an aircraft cabin pressure control valve includes a valve body, one or more valve gates, and one or more walls. The valve body is adapted to mount in the fuselage of an aircraft, and has at least a first flow port, a second flow port, and a flow passage therebetween. Each of the valve gates is mounted on the valve body proximate the first flow port, and is moveable between a plurality of positions relative to the first flow port to thereby control an effective flow area therethrough. The walls are located adjacent to the valve body, and each has at least a distal edge, an inner surface, and an outer surface. Each wall inner surface surrounds at least a portion of the valve gates at least when the gate is

closed, and each wall distal edge is formed at a wall angle relative to the first flow port. The effective flow area through the first flow port varies substantially non-linearly with gate position for gate positions varying from the closed position to a predetermined open position.

- 5 **[0012]** Other independent features and advantages of the preferred outflow control valve will become apparent from the following detailed description, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

[0013] FIGS. 1 and 2 are side and perspective views, respectively, of an aircraft cabin pressure outflow control valve according to an exemplary embodiment of the present invention, with the valve in the fully closed position;

- 15 **[0014]** FIGS. 3 and 4 are side and perspective views, respectively, of the exemplary valve shown in FIGS. 1 and 2, with the valve in the fully open position;

[0015] FIG. 5 is a perspective view of a valve body of a cabin pressure outflow control valve according to an exemplary alternative embodiment of the present invention;

- 20 **[0016]** FIG. 6 is a graph depicting effective flow area vs. valve position for various structural configurations of the valve shown in FIG. 5; and

[0017] FIG. 7 is a side view of a cabin pressure outflow control valve according to another exemplary alternative embodiment of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

- 25 **[0018]** An exemplary embodiment of an air outflow valve that may be used to control aircraft cabin pressure is shown in FIGS. 1-4. As can be seen, the outflow valve 100 includes a valve body 102 having a fluid flow passageway 104 that passes through the valve 100 between a first flow port 106 and a second flow port 108. The valve body 102 is preferably adapted to mount to an aircraft fuselage (not shown),
30 such that the first flow port 106 is in fluid communication with the aircraft cabin and the second flow port 108 is in fluid communication with the ambient environment outside the fuselage.

[0019] The valve 100 includes a valve gate 110 that is rotatable through a plurality of positions, from a fully closed position, as shown in FIGS. 1 and 2, to a

fully open position, as shown in FIGS. 3 and 4, to thereby control cabin pressure in the aircraft cabin into which it is installed. To provide this rotation, the valve gate 110 is rotationally mounted on a shaft 112, which is itself rotationally mounted on the valve body 102 proximate the first flow port 106. The valve gate 110 may be biased
5 toward the fully closed position by aerodynamic pressure, gravity, or by a gravity-assisting biasing element such as a spring. An actuator assembly 114, an embodiment of which will now be described, engages the valve gate 110 to rotate it to the desired position.

[0020] The actuator assembly 114 is preferably mounted on the valve body 102,
10 though it will be appreciated that it could be disposed remote from the valve body 102, and may be any one of numerous known actuator configurations. In the depicted embodiment, the actuator assembly 114 includes a housing 116, one or more motors 118 (shown in phantom in FIG. 3), an actuator arm 120, an actuator shaft 122, and a valve movement tab 124. The motors 118 may be any one of numerous known motor
15 types including, but not limited to electric, hydraulic, and pneumatic, and may be any one of numerous configurations including, but not limited to, linear and rotary motors. The motors 118 are coupled, preferably via appropriate gearing 126, to one end of the actuator arm 120. In the depicted embodiment, the actuator arm 120 is one of
20 numerous types of mechanisms such as, a jackscrew or ball screw, in which rotation of one portion of the mechanism results in translation of another portion. The actuator arm 120 includes a rod end member 128, which is coupled to the actuator shaft 122, and which is in turn coupled to the valve movement tab 124. The valve movement tab 124 is coupled to the valve shaft 112 and, as was alluded to above, engages the valve gate 110 to move it to the desired position. With this configuration,
25 in the unlikely event that one or more of the actuator assembly components failed, air pressure would urge the valve gate 110 toward is fully closed position, providing an inherently fail-safe configuration.

[0021] The position of the valve gate 110 may be expressed in terms of valve angle (α), relative to the first flow port 106. Thus, in the fully closed position (FIGS.
30 1 and 2), the valve angle (α) is zero degrees, and the valve gate 110 blocks substantially the entire first flow port 106, and thus substantially blocks flow between the first 106 and second 108 flow ports. Conversely, in an open position (FIGS. 3 and 4), the valve angle (α) is non-zero, and the valve gate 110 does not block substantially the entire first flow port 106, allowing fluid flow between the first 106 and second

108 flow ports. As will be discussed in more detail below, the effective flow area, and thus the flow resistance between the first 106 and second 108 flow ports, varies with valve angle (α).

5 **[0022]** As FIGS. 1-4 additionally show, a flow influencing wall 130 is coupled to the valve body 102 and extends from the first flow port 106. In the depicted embodiment, the wall 130 includes a distal edge 132, an inner surface 134, and an outer surface 136. The wall distal edge 132 is configured to form an angle (β) relative to the first flow port 106. It will be appreciated that the wall distal edge angle (β) may vary from point to point, but is preferably a constant. As will be discussed in more detail below, the magnitude of the wall distal edge angle (β) is set based on the particular flow characteristics desired from the valve 100. As shown most clearly in FIGS. 1 and 2, the wall inner surface 134 surrounds at least a portion of the valve gate 110 when the valve 100 is in or near its closed position. It will be appreciated that the wall 130 may be separately or integrally formed with, or coupled to, the valve body 15 102.

20 **[0023]** The actuator assembly 114 is adapted to receive valve position control signals from, for example, a controller circuit 138. In response to the received signals, the actuator assembly 114 rotates the valve gate 110 to the commanded valve angle (α). The controller circuit 138 is preferably mounted on the valve body 102, and is configured in either a single channel or dual channel (or more) architecture. In either case, each channel includes the instrumentation and control circuitry that is used, among other things, to supply valve position command signals to the valve actuator assembly 114. The circuitry may be variously configured but, in a particular preferred embodiment, is configured similar to the circuitry described in commonly 25 assigned, and presently pending, U.S. Patent Application Serial No. 10/080,107, entitled "Instrumentation and Control Circuit having Multiple, Dissimilar Sources for Supplying Warnings, Indications, and Controls and an Integrated Cabin Pressure Control System Valve Incorporating the Same," which was filed on February 21, 2002, and the entirety of which is hereby incorporated by reference.

30 **[0024]** The valve 100 illustrated in FIGS. 1-4 has a valve body 102 that is substantially circular in cross-section. It will be appreciated, however, that the valve 100 is not limited to a circular valve body 102. Indeed, numerous cross sections such as, for example, square and rectangular cross sections may also be implemented. An example of a valve body 502 of square cross section is shown in FIG. 5. In this

particular embodiment, three walls 514a-c are coupled to the valve body 502. These three walls 514a-c may be separately or integrally formed with one another, and/or separately or integrally formed with, or coupled to, the valve body 502.

[0025] As was noted above, the wall 130, 514 influences the flow characteristics of the valve 100. In particular, the wall distal edge angle (β) is selected so that the effective flow area of the first flow port 106 is non-linear with respect to valve angle (α), at least around the fully closed position. In this way, flow control is improved when the valve gate 110 is positioned near the fully closed position. This phenomenon is illustrated in FIG. 6, which is a graph depicting effective flow area (as a percentage of full-open) vs. valve angle (α) for various wall distal edge angles (β). For ease of calculation, the graph 600 is based on a valve 100 having a square cross section, such as the one illustrated in FIG. 5, and with coefficient of discharge (C_d) effects ignored. The graph 600 shows that when no walls 130, 514 are provided, the curve 602 of flow area vs. valve angle (α) is substantially linear, with a fairly steep slope, between zero and approximately 20 degrees. Thereafter, the curve 602 exhibits a substantially zero slope for valve angles (α) above 20 degrees.

[0026] However, when walls 130, 514 are included, the curve of flow area vs. valve angle (α) is non-linear, with a significantly reduced slope, for valve angles (α) between zero degrees and a first predetermined valve angle. As FIG. 6 shows, this first predetermined valve angle depends at least in part on the wall distal edge angle (β). For example, for a wall distal edge angle (β) of about 20°, the curve 604 is non-linear for valve angles (α) between 0° and approximately 20°, and is substantially linear for valve angles (α) between this value and a second predetermined valve angle, at which point the curve 604 exhibits a substantially zero slope. Similarly, for wall distal edge angles (β) of approximately 30°, 40°, and 50°, the curves 606, 608, and 610, respectively, are non-linear for valve angles between 30°, 40°, and 50°, respectively, are substantially linear for valve angles (α) up to a second predetermined valve angle, and have a substantially zero slope thereafter. It is also seen that for a wall distal edge angle (β) of approximately 60°, the curve 612 has no substantially linear region. Instead, it is non-linear for valve angles (α) between 0° and approximately 60°, and has a substantially zero slope thereafter.

[0027] The valves illustrated in FIGS. 1-5 are each configured with a single gate 110. However, it will be appreciated that the valve 100 could also be configured with more than one gate 110 mounted on one or more rotationally mounted shafts 110. For

example, FIG. 7 shows a simplified side view of a valve 700 configured with two valve gates 710a and 710b. With this configuration, the valve 700 may include a single flow influencing wall or, as in the depicted embodiment, two flow influencing walls 730a and 730b, one per gate 710a and 710b, respectively.

5 **[0028]** Including one or more flow influencing walls as described above changes the flow area vs. valve angle characteristic curve, such that the slope of the curve, at least around the closed position, is non-linear and significantly less than a valve without the flow influencing walls. This provides improved flow control resolution of the valve around the closed position, which is where a cabin pressure outflow control
10 valve is operated for a significant amount of time. With improved flow control resolution, one or more drawbacks associated with using a fairly simple, and relatively inexpensive type of valve configuration for an outflow valve, such as those described above, may be overcome.

15 **[0029]** While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt to a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention
20 not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS

WE CLAIM:

- 5 1. An aircraft cabin pressure control valve, comprising:
 a valve body (102) adapted to mount on the fuselage of an aircraft and having
 at least a first flow port (106), a second flow port (108), and a flow passage (104)
 therebetween;
 one or more valve gates (110) rotationally mounted on the valve body (102)
10 proximate the first flow port (106), each valve gate (110) rotatable between a plurality
 of valve angles relative to the first flow port to thereby control an effective flow area
 therethrough, wherein each valve gate (110) is in a closed position when the valve
 angle is zero degrees; and
 one or more walls (130) adjacent to the valve body (102), each wall (130)
15 having at least a distal edge (132), an inner surface (134), and an outer surface (136),
 each wall inner surface (134) surrounding at least a portion of at least one of the valve
 gates (110) at least when its valve angle is zero degrees, and each wall distal edge
 (132) formed at a wall angle relative to the first flow port (106),
 whereby the effective flow area through the first flow port (106) varies
20 substantially non-linearly with valve angle for valve angles from zero degrees up to a
 predetermined number of degrees.
2. The valve of Claim 1, wherein the predetermined number of degrees
 depends, at least in part, on the wall angle.
- 25 3. The valve of Claim 1, wherein the first flow port (106) is substantially
 cylindrical in cross section.
4. The valve of Claim 1, wherein the first flow port (106) is substantially
30 trapezoidal in cross section.
5. The valve of Claim 1, wherein one or more of the walls (130) is
 integrally coupled to the first flow port (106).

6. The valve of Claim 1, wherein:
the flow passage (104) is symmetric about a flow axis that extends between
the first (106) and second (108) flow ports; and
5 the first flow port (106) is configured substantially perpendicular to the flow
axis.

7. The valve of Claim 1, wherein:
the flow passage (104) is symmetric about a flow axis that extends between
10 the first and second flow ports; and
the first flow port (106) is configured at a non-perpendicular angle relative to
the flow axis.

8. The valve of Claim 1, further comprising:
15 a controller circuit (138) mounted on the valve body (102) and operable, in
response to one or more aircraft cabin pressure signals, to supply one or more valve
actuation signals; and
a valve actuator (114) mounted on the valve body (102), the valve actuator
(114) adapted to receive the valve actuation signals and operable, in response thereto,
20 to position each valve gate (110) at a valve angle.

9. An aircraft cabin pressure control valve, comprising:
a valve body (102) adapted to mount on the fuselage of an aircraft, the valve
body (102) having at least a first flow port (106), a second flow port (108), and a flow
25 passage (104) therebetween;
one or more valve gates (110) mounted on the valve body (102) proximate the
first flow port (106), each valve gate (110) moveable between a plurality of positions
relative to the first flow port (106) to thereby control an effective flow area
therethrough; and
30 one or more walls (130) located adjacent to the valve body (102), each wall
(130) having at least a distal edge (132), an inner surface (134), and an outer surface
(136), each wall inner surface (134) surrounding at least a portion of the valve gates
(110) at least when the gate is closed, and each wall distal edge formed at a wall angle
relative to the first flow port (106),

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whereby the effective flow area through the first flow port (106) varies substantially non-linearly with gate position for gate positions varying from the closed position to a predetermined open position.

- 5 10. The valve of Claim 9, further comprising:
 a controller circuit (138) mounted on the valve body (102) and operable, in
 response to one or more aircraft cabin pressure signals, to supply one or more valve
 actuation signals; and
 a valve actuator (114) mounted on the valve body (102), the valve actuator
10 (114) adapted to receive the valve actuation signals and operable, in response thereto,
 to position each valve gate (110).

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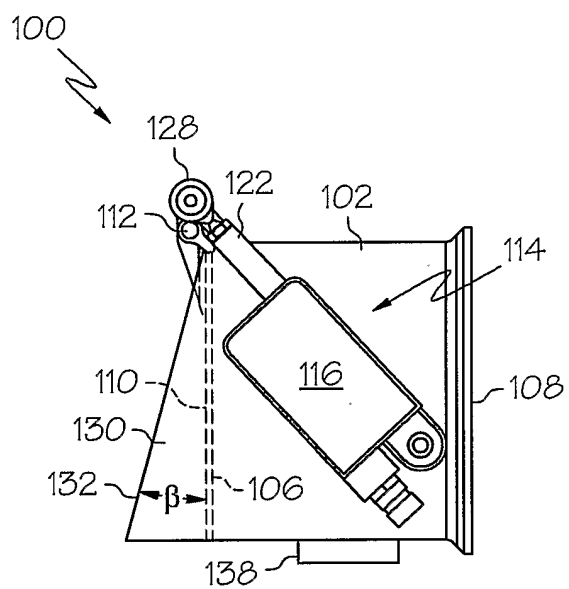


FIG. 1

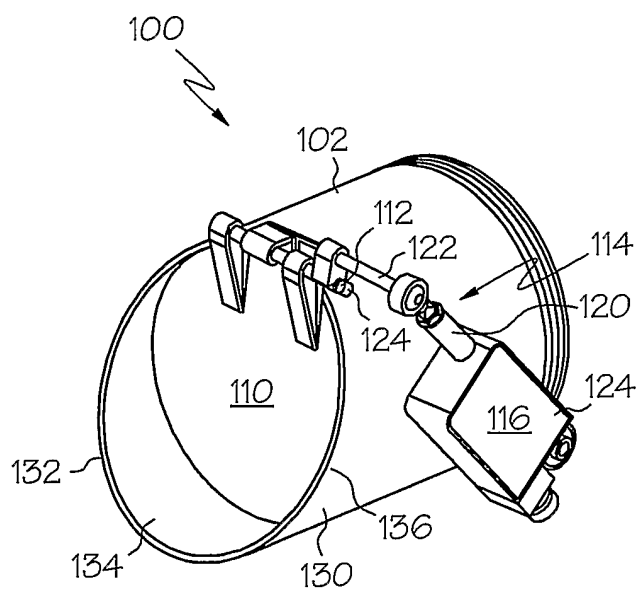


FIG. 2

2 / 3

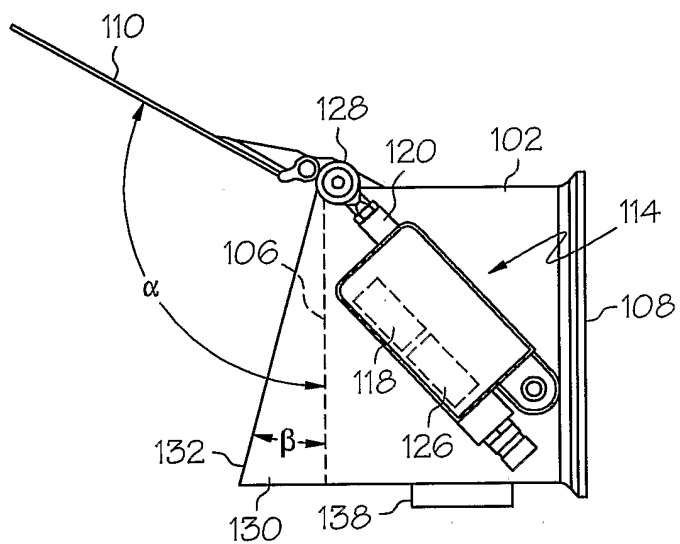


FIG. 3

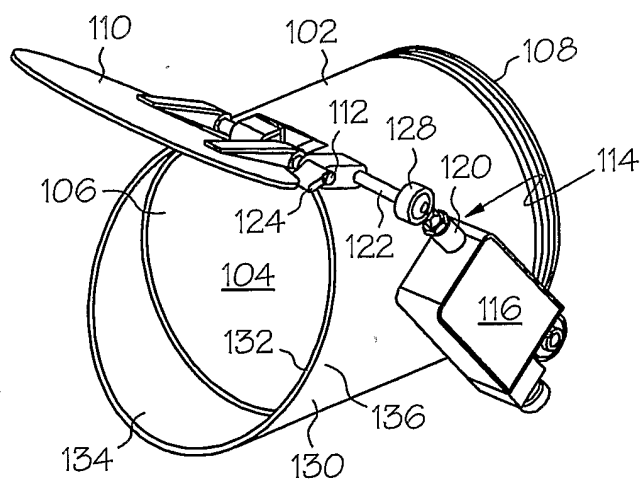


FIG. 4

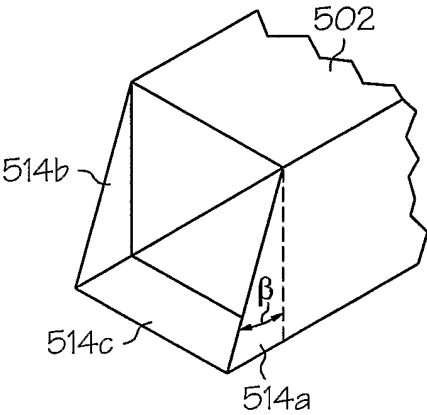


FIG. 5

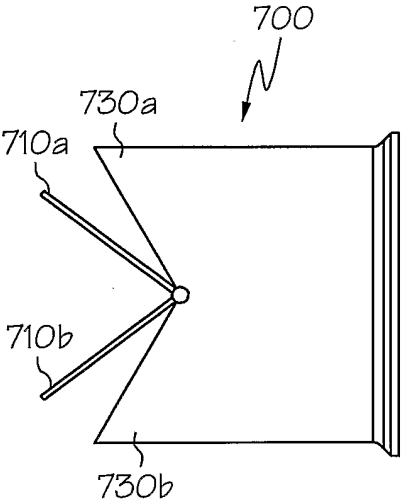


FIG. 7

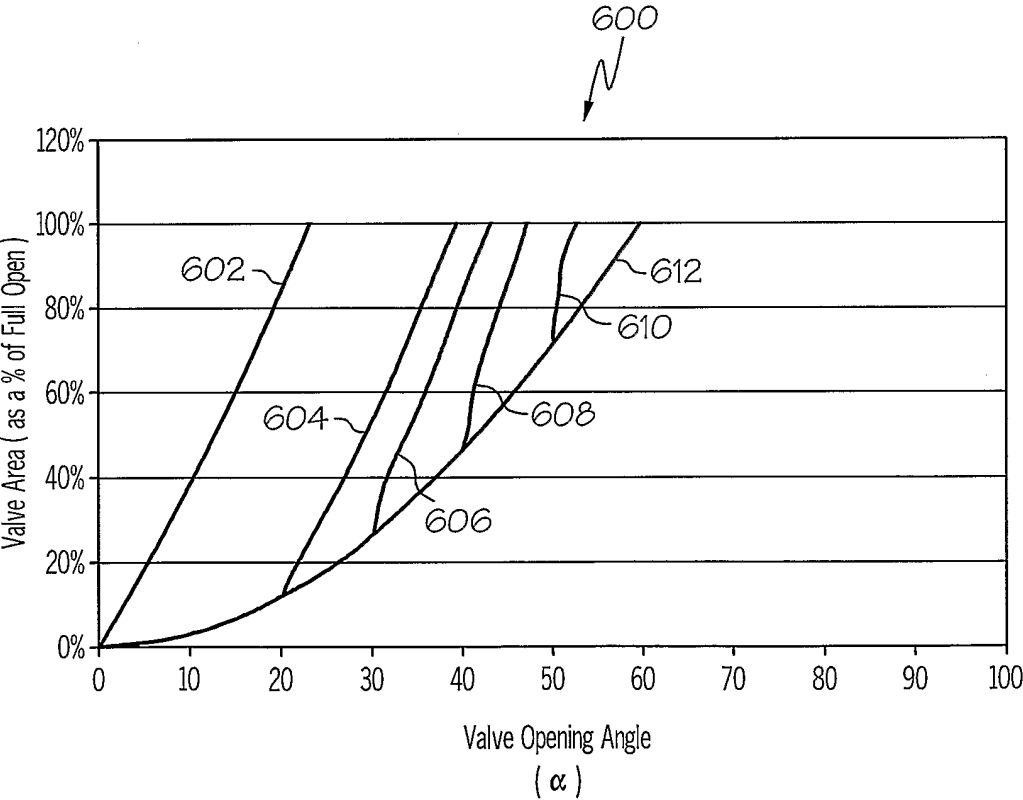


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2004/013528

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B64D13/04

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 7 B64D

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 770 547 A (GARRETT CORP) 20 March 1957 (1957-03-20)	1, 3, 5, 6, 9
Y	the whole document	8, 10
X	US 2 391 197 A (NEVIN SCHWIEN LEO) 18 December 1945 (1945-12-18)	1, 3, 5, 7, 9
Y	the whole document	8, 10
Y	US 5 046 686 A (CARLA FRANCIS ET AL) 10 September 1991 (1991-09-10) column 3, lines 38-60; figure 2	8, 10
X	GB 817 216 A (GARRETT CORP) 29 July 1959 (1959-07-29) figures	1, 6, 9
A	US 5 238 220 A (VU DUNG T ET AL) 24 August 1993 (1993-08-24)	

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

☒ Patent family members are listed in annex.

° Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
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- *O* document referring to an oral disclosure, use, exhibition or other means
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- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search

27 October 2004

Date of mailing of the international search report

15/11/2004

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Salentiny, G

INTERNATIONAL SEARCH REPORT

national application No.
PCT/US2004/013528

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: —
because they relate to subject matter not required to be searched by this Authority, namely:

Claim 2 lacks clarity in the sense of Article 6 PCT, the reasons being given under point VIII of the written opinion. The search examiner has carried out the search for the subject-matter claimed in claim 2 with reference to the embodiments discussed in paragraph '0026! of the description.
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US2004/013528

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