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(71) Applicant (for all designated States except US): **HONEYWELL INTERNATIONAL INC.** [US/US]; Law Department AB/2B, 101 Columbia Road, Morristown, NJ 07962 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **SPELDRICH, Jamie,**

W. [US/US]; 17 East Roosevelt Street, Freeport, IL 61032 (US).

(74) Agent: **BEATUS, Carrie;** Honeywell International Inc., Law Department AB/2B, 101 Columbia Road, Morristown, New Jersey 07962 (US).

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(54) Title: AIRFLOW SENSOR WITH PITOT TUBE FOR PRESSURE DROP REDUCTION

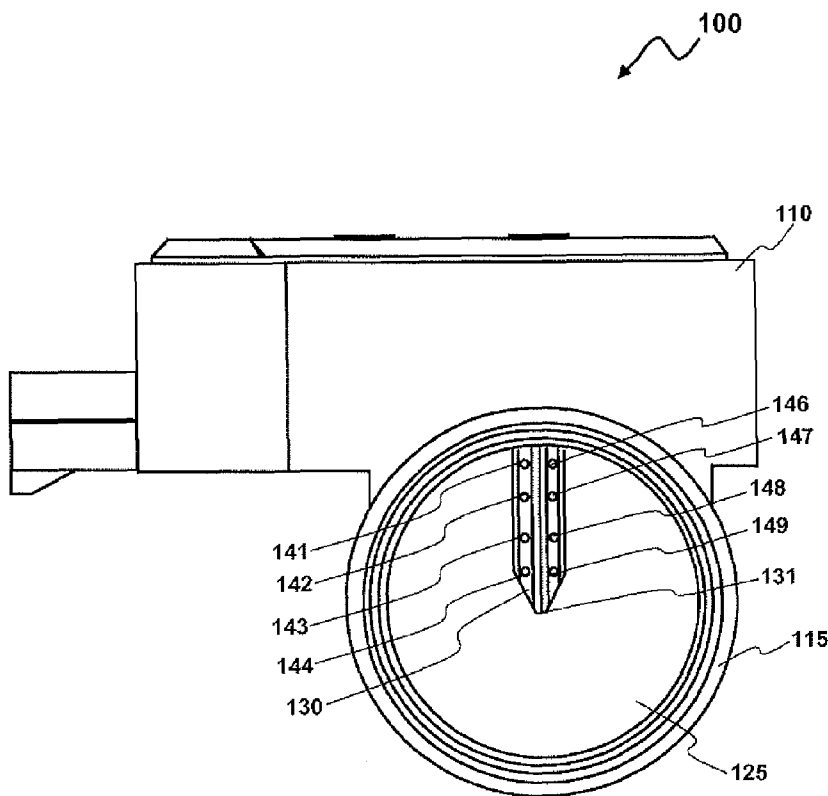


FIG. 1

(57) Abstract: An airflow sensor apparatus for measuring flow rate includes a pitot tube with a bypass channel wherein the pitot tube extends halfway into a flow channel in order to reduce a pressure drop. One or more upstream taps can be spaced along the pitot tube facing into a direction of a flow stream which directs the flow to the bypass channel. At least one or more downstream taps can be located to face perpendicular to the direction of flow, such that the fluid after passing over a flow sensor passes through the downstream tap(s). The upstream tap senses stagnation pressure and the downstream tap senses static pressure which is exerted in all directions in the flow channel in order to determine a velocity pressure based on a difference between pressures.

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AIRFLOW SENSOR WITH PITOT TUBE FOR PRESSURE DROP REDUCTION

TECHNICAL FIELD

[001] Embodiments are generally related to sensor methods and systems. Embodiments are also related to airflow sensors for medical ventilator applications. Embodiments are additionally related to airflow sensors with ultra low-pressure drop.

BACKGROUND OF THE INVENTION

[002] Flow rate control mechanisms are used in a variety of flow systems as a means for controlling the amount of fluid, gaseous or liquid, traveling through the system. The flow control mechanisms can be utilized to regulate flow rates in systems such as ventilators and respirators where, for example, it may be desirable to maintain a sufficient flow of breathable air or provide sufficient anesthetizing gas to a patient in preparation for surgery.

[003] MEMS based flow sensors can be utilized for measuring such flow rates in a variety of commercial, industrial and medical applications. In medical applications, for example, it is often required to accurately measure the flow rates of fluids introduced intravenously to medical patients and thereby control the flow rate of such fluids. In such applications, flow control is an inherent aspect of proper operation, which can be achieved in part by utilizing the flow sensors to measure the flow rate of fluid within the flow system.

[004] Ventilators are medical devices for delivering a breathing gas to a patient. Usually, ventilators employed in hospital critical care units provide a supply of air enriched with oxygen for inspiration by the patient, and may conventionally include controls for either assisting or controlling breathing, exhaled volume indicators, alarms systems, positive end expiratory pressure valves, pressure indicators, gas concentration monitors,

flow indicators, and heated humidifiers for warming and humidifying the breathing gas. Ventilators used in home care are often used to treat obstructive sleep apnea and supply positive air pressure to assist breathing. Manufacturers of medical ventilator equipment require an ultra low pressure drop to insure efficient blower operations.

[005] The majority of prior art airflow sensors utilized for medical ventilators operate on a principle of a flow restrictor, traversing the air stream and measuring the pressure at a number of locations in the duct. The static pressure drives a sample of airflow through a bypass channel where the flow rate is measured.

[006] An alternate technology uses a pitot tube having a probe with an open tip, which is inserted, into the flow field in order to measure a static pressure. The static pressure is an increasing, continuous function of the airflow rate within the tube. The pitot tube extends completely through the main channel of the sensor therefore presents a barrier to the oncoming flow. The problem associated with these sensors is that the sensor itself is responsible for a certain amount of turbulence in the flow channel. Sensor-generated turbulence causes an increase in pressure drop across the sensor as well as noise in the duct system.

[007] Based on the foregoing it is believed that a need exists for an improved airflow sensor that reduces pressure drop and that is adapted to reduce obstruction to the flow. It is believed that the improved flow sensor disclosed herein can address these and other continuing needs.

BRIEF SUMMARY

[008] The following summary is provided to facilitate an understanding of some of the innovative features unique to the embodiments disclosed and is not intended to be a full description. A full appreciation of the various aspects of the embodiments can be gained by taking the entire specification, claims, drawings, and abstract as a whole.

[009] It is, therefore, one aspect of the present invention to provide for improved sensor methods and systems.

[0010] It is another aspect of the present invention to provide for improved airflow sensor with low-pressure drop.

[0011] The aforementioned aspects and other objectives and advantages can now be achieved as described herein. An airflow sensor apparatus for measuring flow rate includes a pitot tube with a bypass channel wherein the pitot tube extends halfway into a flow channel in order to reduce a pressure drop. One or more upstream taps can be spaced along the pitot tube facing into a direction of a flow stream which directs the flow to the bypass channel. At least one or more downstream taps can be located to face perpendicular to the direction of the flow, such that the fluid after passing over a flow sensor passes through the downstream tap(s). The upstream tap senses stagnation pressure and the downstream tap senses static pressure which is exerted in all directions in the flow channel in order to determine a velocity pressure based on a difference between pressures.

[0012] The upstream taps and the downstream taps average the pressure in the bypass channel in order to provide a more accurate reading of the flow in the flow channel. The pitot tube extends halfway into the flow channel hence the obstruction to the flow channel and the pressure drop can be reduced. In addition, this technique of sensing velocity pressure eliminates the need to add pressure drop to the system to measure flow such

as with a flow restrictor or orifice. The velocity pressure can be sensed electronically utilizing the flow sensor or ultra low-pressure sensor. The orientation of the upstream taps and the downstream in this configuration produces the difference between stagnation pressure and drag pressure, which can be correlated to the flow of the fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The accompanying figures, in which like reference numerals refer to identical or functionally-similar elements throughout the separate views and which are incorporated in and form a part of the specification, further illustrate the embodiments and, together with the detailed description, serve to explain the embodiments disclosed herein.

[0014] FIG. 1 illustrates a perspective view of an airflow sensor apparatus, which can be adapted for use in implementing a preferred embodiment;

[0015] FIG. 2 illustrates a cut-away sectional view of the airflow sensor apparatus, in accordance with a preferred embodiment;

[0016] FIG. 3 illustrates a cross sectional view of an airflow sensor, in accordance with a preferred embodiment; and

[0017] FIG. 4 illustrates a cut-away sectional view of an exemplary airflow sensor apparatus, in accordance with a preferred embodiment.

DETAILED DESCRIPTION

[0018] The particular values and configurations discussed in these non-limiting examples can be varied and are cited merely to illustrate at least one embodiment and are not intended to limit the scope thereof.

[0019] Referring to FIG. 1 a perspective view of an airflow sensor apparatus 100 is illustrated, in accordance with a preferred embodiment. The airflow sensor apparatus 100 includes a housing 110 defining a flow channel 125 into which an entering fluid may flow from a flow system. Note that as utilized herein the term "fluid" can refer to a liquid or a gas. The flow channel 125 can be defined by a flow channel wall 115. The flow channel 125 preferably has a cross-sectional shape and size compatible with that of existing flow systems, such as to fit conical connector as used in ventilators and respirators. A pitot tube 130 extends halfway into the flow channel 125. The pitot tube 130 includes one or more upstream taps 141, 142, 143, 144, 146, 147, 148 and 149 shaped with a circular cross-sectional shape that can be oriented upstream in flow channel 125 to face into the direction of fluid (e.g., gas) flow.

[0020] The taps 141, 142, 143, 144, 146, 147, 148 and 149 can be implemented as upstream taps that face into the flow of fluid. As utilized herein, the term "tap" can refer to a small opening that permits flow of a liquid or gas. The pitot tube 130 additionally includes one or more downstream taps (not shown) that face perpendicular to the fluid flow or opposite the direction of the flow. The downstream taps function as exhaust taps for the bypass channel.

[0021] Referring to FIG. 2 a cut-away sectional view of an airflow sensor apparatus 100 is illustrated, in accordance with a preferred embodiment. The fluid can pass through the flow channel 125 in the direction as indicated by arrow 126 via an inlet end 155, with the fluid exiting the flow channel 125 at an outlet end 165. A flow sensor die 190 is disposed

in a bypass-sensing channel 170 parallel to the flow channel 125. The sensor die 190 and the flow channel 125 are located adjacent which is protected by a cover 116, which in turn is situated within a housing 110. A cover 116, disposed against the rear side of the substrate 117 opposite the sensor die 190 protects the sensor die 190 from environmental effects.

[0022] The pitot tube 130 is disposed in the flow channel 125 and aligned perpendicular to the flow channel 125. The pitot tube 130 has a leading edge 131 and is preferably sharpened as seen in FIG. 1 such that the fluid smoothly enters the tube 130 thus minimizing or substantially reducing turbulence and droplet shear. The pitot tube 130 extends halfway into the flow channel which reduces pressure drop and obstruction to flow. The upstream taps 141, 142, 143 and 144 in the pitot tube 130 leads to the low resistance flow channel 125, which can direct bypass flow to the sense die 190. After passing over the sense die 190, the bypass flow of fluid continues in a low resistance flow path and exhausts through downstream taps 146, 147, 148 and 149, which are oriented opposite the direction of flow.

[0023] The fluid flows through the flow channel 125 in the direction indicated by arrow 126, a portion of the fluid flows through the upstream taps 141, 142, 143 and 144 in the pitot tube 130 to the bypass channel 170 so that the flow sensor die 190 can measure the flow rate of the fluid in the flow channel 125 indirectly without being exposed to the damage or fluctuating conditions existing in typical flow channels.

Figure 3 is similar to Figure 2 except downstream taps are oriented opposite the flow direction.

[0024] Referring to FIG. 4 a cross sectional view of an airflow sensor 200 is illustrated, in accordance with a preferred embodiment. The sensor 200 includes an upstream sensing element 191, a downstream sensing

element 192 and a central heating element 193. The heating element 193 and sensing elements 191 and 192 comprises of resistive thin films (not shown), which comprise an electrical bridge whose output is analogous to the differential pressure applied to the sensor apparatus 100. The sensing elements 191 and 192 can be implemented as, for example, a MEMS type airflow sensor. It can be appreciated, of course, that the sensing elements 191 and 192, may be configured in the context of other types of sensor designs, not merely MEMS-type configurations. The fluid will flow across the upstream sensing element 191, the downstream sensing element 192 and the heating element 193. Under no flow conditions, the upstream sensing element 191 and the downstream sensing element 192 would both read the same temperature due to the heating element 193, i.e., both sensors would have the same measured resistance values.

[0025] As the fluid enters the upstream port 150 of the pitot tube 130, the upstream sensing element 191 senses the average sensor impact pressure of flowing fluid to establish a high pressure value resulting in a reduction of temperature. The downstream sensing element 192 senses low pressure, which forms an exhaust port 180 for the bypass channel 170 resulting in an increase of temperature. The change in temperatures produces a corresponding change in the resistance values of the sensor 200. The sensor 200 transforms the respective high and low fluid pressures into an electrical signal whose character is a function of the differential pressure (DP), that is the difference between the sensed high and low fluid pressures. The upstream taps 141, 142, 143 and 144 and the downstream taps 146, 147, 148 and 149 averages the pressure in the bypass channel 170 in order to provide a more accurate reading of the flow in the flow channel 125.

[0026] Note that as utilized herein the acronym "MEMS" refers generally to term "Micro-electro-mechanical Systems". MEMS devices refer to mechanical components on the micrometer size and include 3D

lithographic features of various geometries. They are typically manufactured using planar processing similar to semiconductor processes such as surface micromachining and/or bulk micromachining. These devices generally range in size from a micrometer (a millionth of a meter) to a millimeter (thousandth of a meter). At these size scales, a human's intuitive sense of physics do not always hold true. Due to MEMS' large surface area to volume ratio, surface effects such as electrostatics and wetting dominate volume effects such as inertia or thermal mass.

[0027] MEMS devices can be fabricated using modified silicon fabrication technology (used to make electronics), molding and plating, wet etching (KOH, TMAH) and dry etching (RIE and DRIE), electro discharge machining (EDM), and other technologies capable of manufacturing very small devices. MEMS sometimes go by the names micromechanics, micro machines, or micro system technology (MST). While the inserted position of the sensor shown in FIG. 2 is preferred for the illustrated design of pitot tube 130, other configurations are possible and may even be favored for pitot tubes of different design and configuration.

[0028] Referring to FIG. 4 cut-away sectional view of the airflow sensor apparatus 300 is illustrated, in accordance with an alternative, but preferred embodiment. Note that in FIGS. 1-4, identical or similar parts or elements are generally indicated by identical reference numerals. The design of apparatus 300 thus requires one or more upstream taps 141, 142, 143 and 144, which face into the flow direction 126 as shown in FIG. 2 that is to be measured. The upstream taps 141, 142, 143 and 144 can direct the flow of fluid to the sensor die 190 (e.g., MEMS sensor). The sensor die 190 and the bypass channel 170 are located adjacent a housing 110.

[0029] The pitot tube 130 upstream taps 141, 142, 143 and 144 creates a pressure drop across the upstream port 150 and down stream port 160 of the bypass channel 170 which facilitates fluid flow into the bypass

channel 170. This pressure drop, or pressure differential, is dependent on pitot tube 130 geometry and increases with flow rate. Furthermore, the fluid in the flow channel 125 will have an increasingly turbulent flow as the flow rate of the fluid increases, i.e., an increasing non-uniform pressure and velocity across a given plane orthogonal to the direction of flow. In response, by reducing the pitot tube 130 to half of the flow channel 125 reduces pressure drop, straightens and luminaries the flow in the flow channel 125, thereby reducing turbulence. The pitot tube 130 reduces turbulence by forcing the fluid to flow through other half of the flow channel 125.

Figure 6 shows the pitot tube with a up and downstream flow straightener protruding into the flow to enhance flow stability.

[0030] It will be appreciated that variations of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Also that various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

CLAIMS

What is claimed is:

1. A flow sensor apparatus, comprising:
 - a pitot tube having a bypass channel, said pitot tube extending transversely halfway into a flow channel with respect to the direction of flow of a fluid within said flow channel;
 - at least one upstream tap spaced apart along said pitot tube facing into a direction of a fluid flowing through said flow channel thereby creating an upstream port for said bypass channel and adapted to direct said fluid to a sensor adapted to sense the flow of said fluid; and
 - at least one downstream tap spaced apart along said pitot tube and facing perpendicular to said direction of said fluid in order to determine a velocity pressure based on a difference between a pressure identified by said at least one upstream tap and a pressure identified by said at least one downstream tap.
2. The apparatus of claim 1 further comprising;
 - a housing including a wall that defines said pitot tube with said bypass channel through which said fluid flows.
3. The apparatus of claim 2, wherein said housing further comprises an inlet end and an outlet end and are adapted for coupling the apparatus to a flow system.
4. The apparatus of claim 1, wherein said sensor comprises a MEMS flow sensor with an upstream sensing element, a downstream sensing element and a heating element.
5. The apparatus of claim 1 wherein said pitot tube extend transversely halfway into said flow channel minimizes obstruction to said fluid flow.

6. The apparatus of claim 1 wherein said Pitot tube has a sharp leading edge for substantially reducing turbulence and pressure drop.

7. A flow sensor apparatus, comprising:

a housing including a wall defining a pitot tube including a bypass channel through which fluid is enabled to flow, said pitot tube defined by said housing extending transversely halfway into a flow channel with respect to the direction of flow of a fluid within said flow channel;

at least one upstream tap spaced apart along said pitot tube facing into a direction of a fluid flowing through said flow channel thereby creating an upstream port for said bypass channel and adapted to direct said fluid to a sensor adapted to sense the flow of said fluid; and

at least one downstream tap spaced apart along said pitot tube and facing perpendicular to said direction of said fluid in order to determine a velocity pressure based on a difference between a pressure identified by said at least one upstream tap and a pressure identified by said at least one downstream tap.

8. A flow sensor apparatus, comprising:

a pitot tube having a bypass channel, said pitot tube extending transversely halfway into a flow channel with respect to the direction of flow of a fluid within said flow channel;

at least one upstream tap spaced apart along said pitot tube facing into a direction of a fluid flowing through said flow channel thereby creating an upstream port for said bypass channel and adapted to direct said fluid to a flow sensor;

a flow sensor adapted to sense the flow of said fluid from said upstream port; and

at least one downstream tap spaced apart along said pitot tube and facing perpendicular to said direction of said fluid in order to determine a velocity pressure based on a difference between a pressure identified by said at least one upstream tap and a pressure identified by said at least one

downstream tap.

9. The apparatus of claim 8 further comprising;
a housing including a wall that defines said pitot tube with said bypass channel through which said fluid flows.
10. The apparatus of claim 8, wherein said sensor comprises a MEMS flow sensor with an upstream sensing element, a downstream sensing element and a heating element.

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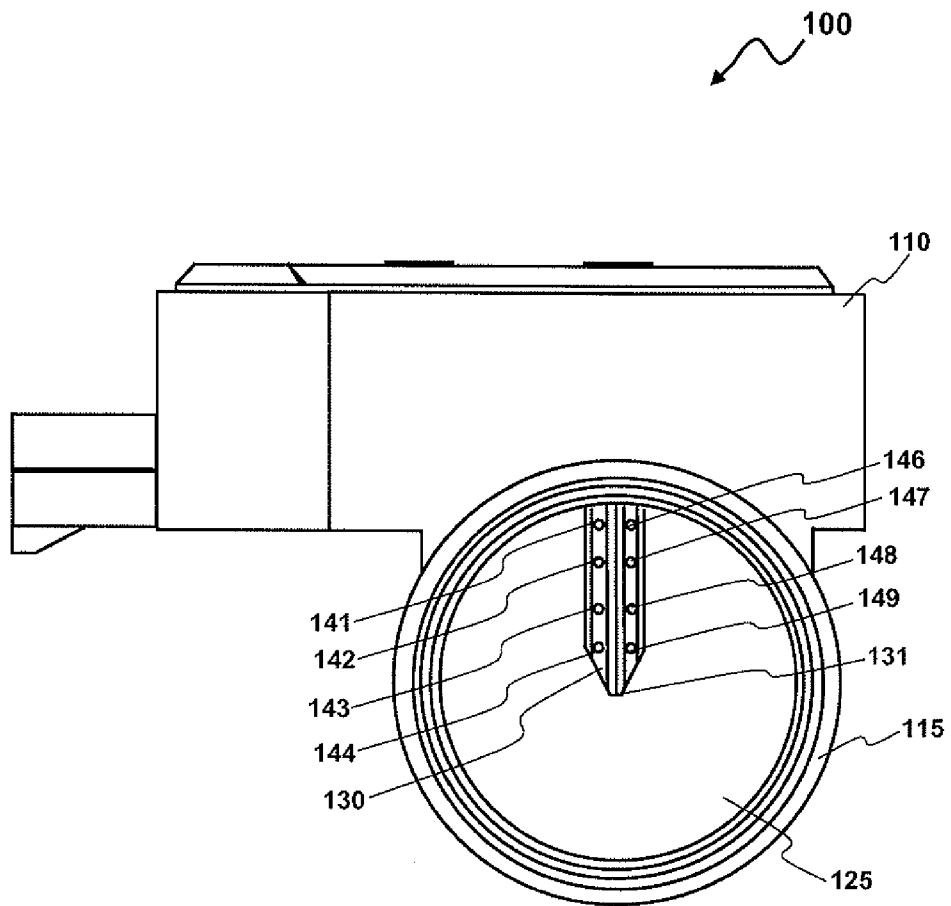


FIG. 1

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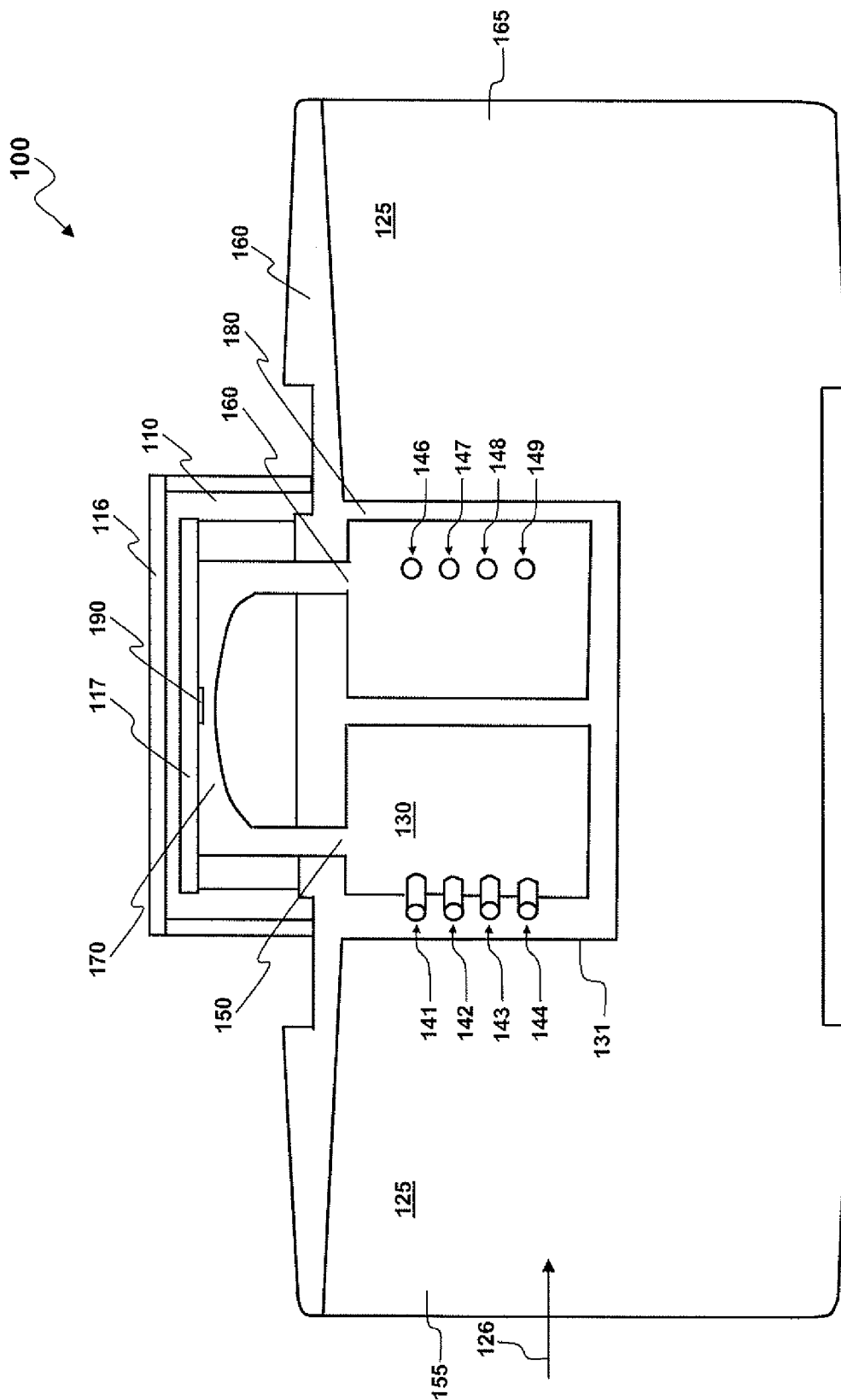


FIG. 2

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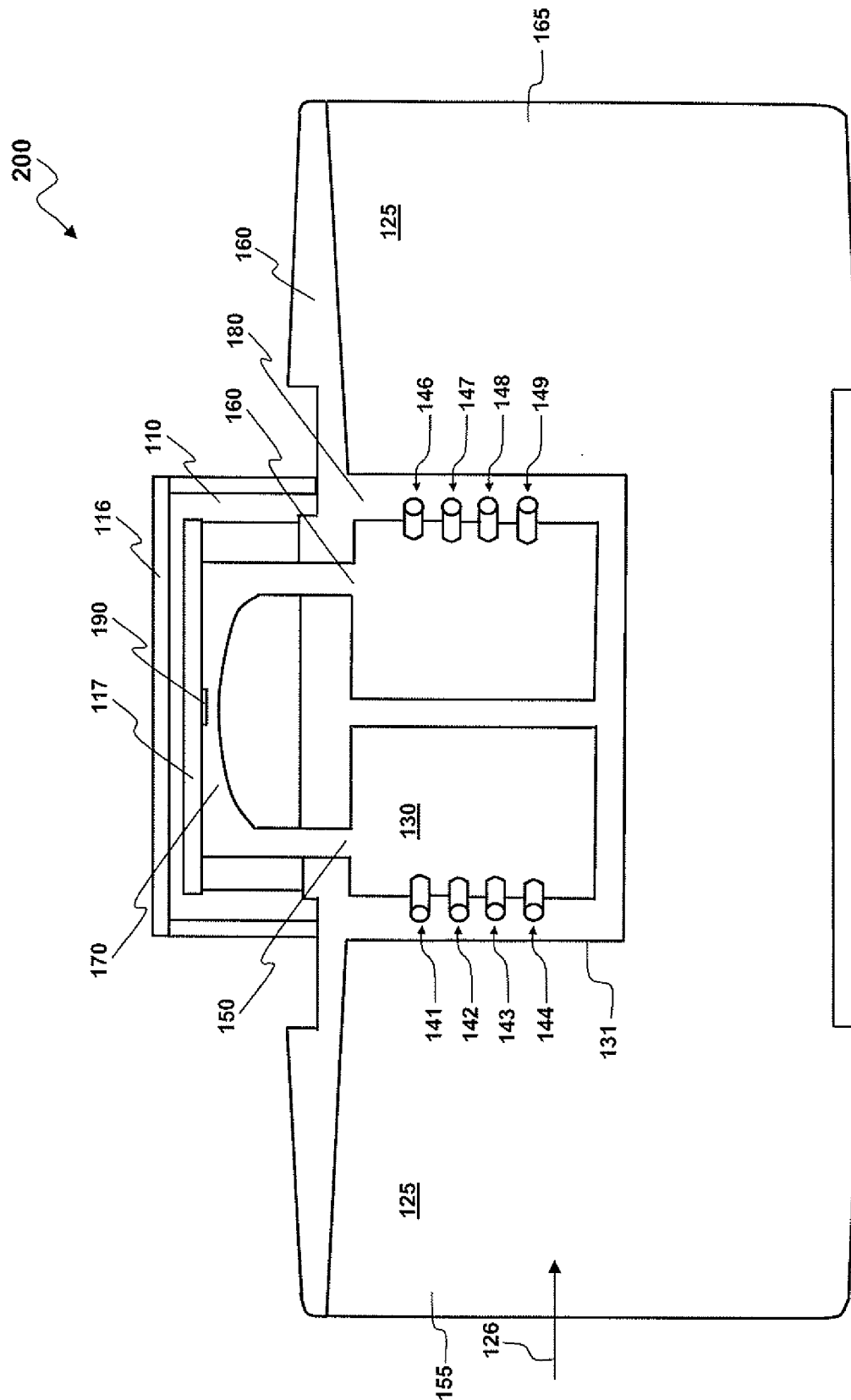


FIG. 3

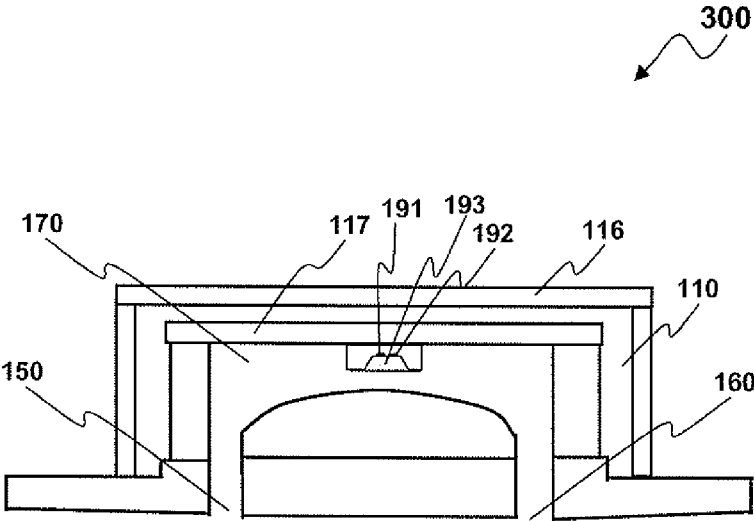


FIG. 4

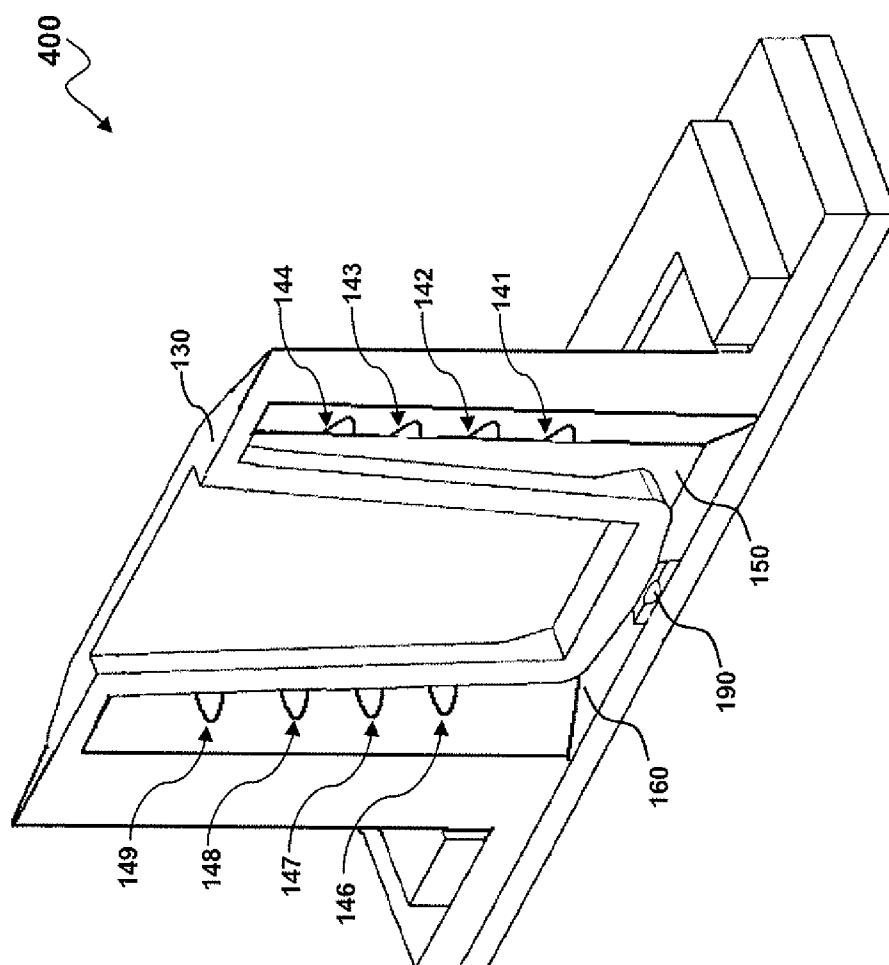


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/084349**A. CLASSIFICATION OF SUBJECT MATTER*****G01F 1/42(2006.01)i, G01F 1/68(2006.01)i, G01F 1/46(2006.01)i, B81B 7/00(2006.01)i, G01F 15/00(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)

IPC8 G01F1/42, G01F 1/68, G01F 1/46, B81B 7/00, G01F 15/00

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

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

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

eKIPASS(KIPONET) & keywords: airflow, sensor, pitot, tube, bypass, extend, tap

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US6164143A(DIETERICH STANDARD INC) 26 DEC 2000 see the entire documents	1-10
A	US5736651A(JAMES R. BOWERS) 7 APR 1998 see the entire documents	1-10
A	US4546655(MICHAEL VICTOR) 15 OCT 1985 see the entire documents	1-10

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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Korean Intellectual Property Office
Government Complex-Daejeon, 139 Seonsa-ro, Seo-
gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

CHUNG, Sang Tae

Telephone No. 010-9908-9225



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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date

US6164143

26.12.2000

NONE

US5736651

07.04.1998

NONE

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15.11.1985

NONE