(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 843 106 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**10.10.2007 Bulletin 2007/41**

(51) Int Cl.:
***F24F 11/04*** *(2006.01)*

(21) Application number: **07102278.4**

(22) Date of filing: **13.02.2007**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR**
Designated Extension States:
**AL BA HR MK YU**

(30) Priority: **03.04.2006 SE 0600749**

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(54) **Airflow regulation device and method**

(57) Device for regulating the flow (Q) of air supplied to an isolated cell (10,12) comprising a duct (28) having an air inlet (30) and two air outlets (32) located on opposite sides/parts of the duct (28) or a plurality of such pairs of outlets (32). The device also includes a damper that comprises a displaceable element (36) that is arranged to move over said at least two air outlets (32) in order to adjust the cross sectional area (A) of said at least two air outlets (32). The device further comprises means to determine the pressure of air upstream of the damper ($p_1$), means to determine the pressure of air downstream of the damper ($p_2$), means to determine the cross sectional area (A) of said at least two outlets (32), means to calculate the air flow (Q) or pressure that is supplied to the isolated cell (10,12) through said at least two outlets (32) of the duct (28) and actuation means (38,40) to displace the displaceable element (36) in order to obtain a desired air flow. The displaceable element (36) comprises two opposing gates whereby one of said gates (42) is arranged to open, partly obstruct or close one or more air outlets (32) located on one side/part of the duct (28) and the other gate (44) is arranged to open, partly obstruct or close one or more air outlets (32) located on the opposing side/part of the duct (28) in order to achieve the desired air flow.

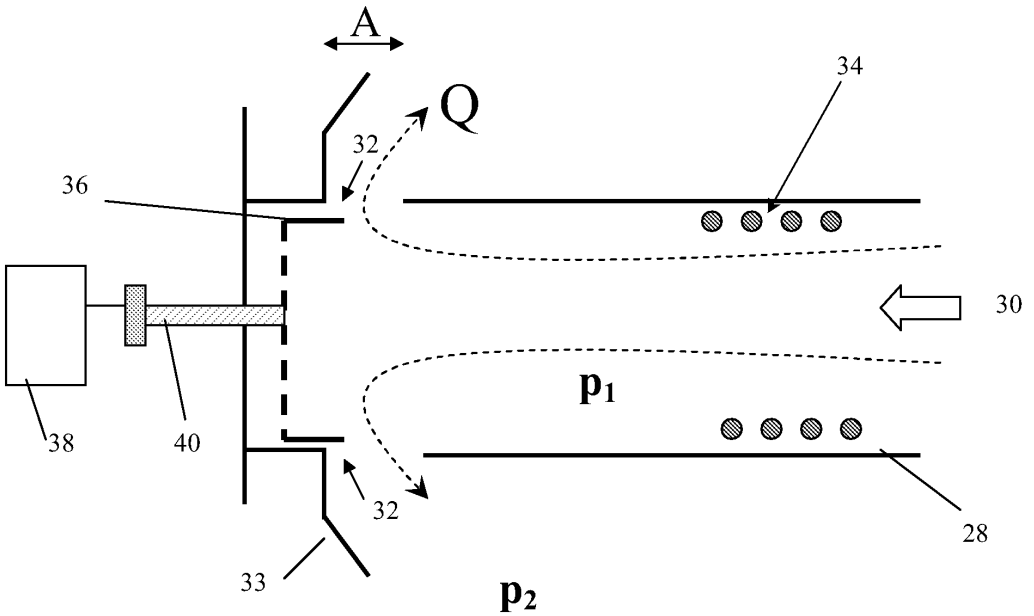



Fig. 2

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## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to a device and method for the regulation of fluid, such as air, supplied to an isolated cell, such as a cabin on a sea-going vessel, such as a large passenger ship, or a fixed or floating offshore installation.

### BACKGROUND OF THE INVENTION

**[0002]** Considerable demands are placed on the ventilation systems of passenger ships. A ventilation system has to provide a comfortable indoor climate, irrespective of whether the ship is traveling through a tropical or an arctic climate and irrespective of the activities taking place on board.

**[0003]** When ventilating isolated cells, such as cabins on board a ship, the isolated cells are supplied with pretreated air from one or more centrally located air-handling units via a system of ducts. The supply air is usually, filtered, cooled or heated and dehumidified or humidified fresh air from the outside of the ship. The temperature of supply air is usually between 5 and 15 °C when it leaves the air-handler in order to always be able to meet any demand for cool air in any one of the cabins supplied by said central air-handler. Each cabin is usually equipped with a local room temperature regulating device at the end of a supply air duct. Air is extracted from the cabin via exhaust-air ducts that extract used air to the outside of the ship.

**[0004]** In some cases means are provided to control the quantity of air being delivered to each cabin in order to control the cabin temperature and to save energy. A variable air volume control device (a so-called "VAV air terminal device") varies the amount of conditioned air that is supplied to a cabin. Such a device maintains a desired temperature within the cabin by varying the quantity of conditioned air supplied to the cabin and/or by heating the supply air using a built-in supply air heater in response to the cabin temperature deviation from a set point of a thermostat.

**[0005]** Conventional VAV air terminal devices have means to maintain the air flow between a low limit that is dictated by the minimum statutory level of ventilation (exchange of stale air) and a high limit based on the maximum calculated thermal load that the cabin in question can be subjected to. The latter limit serves the purpose of limiting the required maximum air-handler output capacity. Such VAV air terminal devices usually comprise means to establish the actual airflow by means of differential pressure measurement or direct airflow measurement in the air stream.

**[0006]** Conventional airflow regulation devices are however noisy, complex, expensive and have a high energy consumption. Such devices often comprise two perforated surfaces that are displaced with respect to one another, whereby the total perforation area is either increased or decreased. Furthermore such devices often become clogged with dust and debris on account of the geometry of their flow regulating damper function, which would be a significant disadvantage if such a device were used in a ship due to the presence of large amounts of dust, insulation material fibres and other light debris which invariably remain inside the supply duct system after its construction. Such debris is conveyed by the supply fan air pressure through the duct system to the airflow regulation air terminal device where it may accumulate and block the opening(s) of a regulation damper. If the size of the debris exceeds the size of the perforations in said surfaces, which are usually 8-12 mm in diameter, the device has to be regularly cleaned, which can be time consuming and complex, especially since airflow regulation devices are usually difficult to access.

**[0007]** Swedish patent no. 510 211 discloses a measuring and control unit for air inlet and air outlet devices, which comprises a terminal unit in the form of a casing, to which an air outlet or air inlet device is coupled. The terminal unit has a device for controlling the air flow and the pressure and comprises a perforated plate with a moveable damper plate on the surface. An actuation force of high magnitude is required to displace the damper plate, especially when it's in an almost closed position because of the internal pressure of the terminal unit that acts on the damper plate.

### SUMMARY OF THE INVENTION

**[0008]** An object of the present invention is to regulate the airflow supplied to an isolated cell, reliably and precisely in a simple and novel way.

**[0009]** This object is achieved by a device that a duct having an air inlet and two air outlets located on opposite sides/parts of the duct or a plurality of such pairs of outlets and a damper that comprises a displaceable element that is arranged to move over said at least two air outlets in order to adjust the cross sectional area (A) of said at least two air outlets. The device also comprises means to determine the pressure of air upstream of the damper ($p_1$), means to determine the pressure of air downstream of the damper ($p_2$), means to determine the cross sectional area (A) of said at least two outlets, means to calculate the air flow (Q) or pressure that is supplied to the isolated cell through said at least two outlets of the duct and actuation means to displace the displaceable element in order to obtain a desired air flow. The displaceable element comprises two opposing gates whereby one of said gates is arranged to open, partly obstruct or close one or more air outlets located on one side/part of the duct and the other gate is arranged to open, partly obstruct or close one or more air outlets located on the opposing side/part of the duct in order to achieve the desired air flow. The expression "opposing gates" is intended to mean gates that are placed substantially opposite one another on opposing sides or parts of a duct. The force

of the internal pressure of the duct or apparatus which acts on the first gate equals the force acting on the second gate and these forces of equal magnitude acting in opposing directions cancel out one another. This results in the displaceable element being easy to displace even if the air outlets are almost completely closed.

**[0010]** It should be noted that the duct may be of any polygonal or non-polygonal shape. If the duct is substantially circular and therefore devoid of "sides" the pair(s) of air outlets are located on opposing parts of the duct. Even though the ventilation systems of ships are subjected to high pressures (typically in the range of 200-1500 Pa) the air pressure inside the duct does not influence the actuation force of the displaceable element even if said at least two air outlets of the duct are almost closed due to the provision of two air outlets located on opposite sides/parts of the duct.

**[0011]** The damper arrangement is designed in such a way that it cannot accumulate fibres or other debris and large flow induced vortices are broken up into smaller ones thus converting low frequency noise into middle or high frequency noise that can be attenuated sufficiently within the apparatus by means of a resistive technique before it reaches the inlet or the outlet of the apparatus regardless if the apparatus is used to control the supply- or exhaust air.

**[0012]** The measured differential air pressure may be incorporated into a derivation of the Bernoulli equation to determine the air flow rate through the device. The air flow rate, Q (in litres/second), may namely be determined from the expression:

$$Q = c(A)\sqrt{\Delta P}$$

where c(A) is a constant whose magnitude depends on the cross sectional area (A) of said at least two air outlets and where $\Delta P$ is the differential pressure across the said at least two air outlets.

**[0013]** It should be noted that the cross sectional area of said at least two air outlets varies in proportion to the displacement of the displaceable element. The displacement of the displaceable element in relation to a fixed point may therefore be used to establish the non-linear relationship between said differential pressure, said displacement and the actual airflow through said device. The device further comprises means to calculate the airflow that is supplied to the isolated cell through said at least two air outlets of the duct and actuation means to displace the displaceable element by a predetermined and exact amount in order to obtain a desired airflow.

**[0014]** Such a device, by virtue of the design of the displaceable element, eliminates the effect that the internal pressure would otherwise have on the displaceable element area, and hence on the actuation force of the damper mechanism.

**[0015]** The inventive device, whose construction is simple, facilitates installation, replacement and maintenance work has a low consumption of energy, is relatively inexpensive and it's damper arrangement design results in low pressure-induced forces on the displaceable elements which in turn gives rise to a low actuation force of the damper arrangement.

**[0016]** The inventive device has a low internal pressure drop since the mass flow though the device is established mathematically using the differential pressure across the damper arrangement together with the cross sectional area of said at least two air outlets which is always known since the damper position relative a fixed point is always known. The need for an additional flow restriction across which the differential pressure drop could be measured is therefore avoided.

**[0017]** Furthermore the function, geometry and size and dimensions of said at least two air outlets may be arranged so that dust, fibres or other debris will not accumulate in front of the damper arrangement the duct. The cross sectional area of the air outlets increases as the damper is opened. If an air outlet becomes blocked, by a piece of mineral wool for example, the device automatically detects an undesired air flow reduction and opens the damper in order to increase the air flow whereby the piece of mineral wool will be blown through the air outlet. The device will then regulate the air flow back to restore the desired air flow. The device is therefore self-cleaning and blockages will not be able to permanently affect the air flow negatively.

**[0018]** The inventive device therefore provides pressure independent airflow regulation of air for ventilation and temperature control of an isolated cell, such as a passenger cabin on a sea-going vessel or a fixed or floating offshore installation. The invention may also be used to match the air quantity supplied to an isolated cell with the air quantity extracted from such a cell irrespective of pressure variations, in absolute and relative terms, in the supply-and exhaust duct systems. The invention has self-cleaning properties in respect to dust and debris present in the air that passes the device.

**[0019]** According to an embodiment of the invention the device comprises vortex reducing means to break up large flow induced vortices into smaller vortices, such as at least one perforated plate, located downstream of said at least two air outlets. Low frequency noise, which is often generated by large flow induced vortices in conventional VAV air terminal devices when their damper arrangement is almost closed, is thus converted into intermediate or high frequency noise that can be attenuated sufficiently, by means of a simple and inexpensive resistive technique, before it reaches the inlet or the outlet of the apparatus utilising the inventive device regardless of whether the device is used to regulate the supply or exhaust air flow.

**[0020]** According to another embodiment of the invention the device comprises air flow diverting means, located downstream of said at least two air outlets, to direct

the air flow in a particular direction. The air flow direction can therefore be changed without suffering an additional pressure loss in the system. A single component, such as perforated diverter plates that direct air in a particular direction on leaving said at least two air outlets, can provide the vortex reducing means and flow diverting means.

**[0021]** According to a further embodiment of the invention said at least two opposing plates are thin, i.e. the thickness of said at least two opposing gates is less than 5mm, preferably less than 3mm and most preferably less than 2mm.

**[0022]** According to an embodiment of the invention the displaceable element is a slideably, pivotably or rotatably mounted element.

**[0023]** According to a further embodiment of the invention the device comprises actuation means to displace the displaceable element automatically whereby said actuation means are responsive to an output of a sensor or control unit that is indicative of the desired airflow. According to an embodiment of the invention said actuation means comprise a motor and a control linkage. Alternatively the displaceable element may be controlled or displaced manually, for example by the movement of a lever to which the displaceable element is mechanically linked. For example a user, such as the occupant of a cabin on a cruise ship, may select or vary the damper position so as to control the volume of air entering the cabin.

**[0024]** The present invention also concerns a ventilation system for ventilating at least one isolated cell, which comprises a device according to any of the embodiments of the invention. According to an embodiment of the invention said at least one isolated cell comprises an air inlet and an air exhaust and an air supply regulating device is mounted in the vicinity of said air inlet and/or air exhaust in order to regulate the flow of air entering and/or leaving the isolated cell. According to another embodiment of the invention the ventilation system comprises means to heat and/or cool the air supplied to said at least one isolated cell and means to regulate the temperature of said at least one isolated cell by air flow control.

**[0025]** The present invention further concerns a method for regulating the flow (Q) or pressure of air supplied to an isolated cell through a duct that comprises a damper, whereby the duct comprises an air inlet and two air outlets located on opposite sides/parts of the duct or a plurality of such pairs of outlets. The method comprises the steps of determining the pressure of air upstream of the damper ($p_1$), determining the pressure of air downstream of the damper ($p_2$), determining the cross sectional area (A) of said at least two air outlets, calculating the air flow (Q) or pressure supplied by the duct and adjusting the cross sectional area (A) of said at least two air outlets by displacing an element that comprises two opposing gates. One of said gates is arranged to open, partly obstruct or close one or more air outlets located on one side/part of the duct and the other gate is arranged to open, partly obstruct or close one or more air outlets located on the opposing side/part of the duct in order to achieve the desired air flow.

**[0026]** According to an embodiment of the invention the method comprises the step of actuating the displaceable element automatically on receiving a signal from a sensor or control unit, which is indicative of the desired air flow.

**[0027]** According to another embodiment of the invention the method comprises the step of regulating the air flow so that the flow of air supplied to the isolated cell substantially corresponds to the flow of air evacuated from the isolated cell. Conventionally all spent air (exhaust air) is sucked through ducts back to a central air-handling unit. Since the return of spent air to the central air handling unit typically takes place without air volume control, undesirable imbalance between the amount of air supplied to an isolated cell and the amount of air evacuated therefore may occur. To counteract this imbalance it is therefore advantageous if an air conditioning system comprises means to control the air flow in and out of an isolated cell so as to match the amount of evacuated air to the supply air at all times.

**[0028]** According to a further embodiment of the invention the method comprises the step of heating and/or cooling the air supplied to the isolated cell and regulating the temperature of the isolated cell by air flow control.

**[0029]** The present inventions also concerns a computer program product that comprises a computer program containing computer program code means arranged to cause a computer or a processor to execute at least one of the steps of a method according to any of the embodiments of the invention, stored on a computer-readable medium or a carrier wave and an electronic control unit (ECU) comprising such a computer program product.

**[0030]** The present invention further concerns a seagoing vessel, such as a passenger ship or other movable or fixed offshore installation that is divided into a plurality of isolated cells, such as cabins, public spaces and/or non-public spaces such as, for example, engine rooms, storage spaces and/or lift shafts, which comprises a device, a ventilation system, an air terminal device or an ECU according to any of the embodiments of the invention or which utilizes a method according to any of the embodiments of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0031]** The present invention will hereinafter be further explained by means of non-limiting examples with reference to the appended figures where;

Figure 1 is a schematic view of two adjacent cabins of a passenger ship which are equipped with a ventilation system according to an embodiment of the invention, viewed from above,

Figure 2 shows a device according to an embodiment

of the invention,

Figure 3 is a flow diagram showing the steps of a method according to an embodiment of the invention.

Figure 4 is a perspective view of a duct that contains a slidably mounted plate according to an embodiment of the invention, and

Figure 5 shows a slidably mounted plate according to an embodiment of the invention.

**[0032]** It should be noted that the drawings have not been drawn to scale and that the dimensions of certain features have been exaggerated for the sake of clarity.

DETAILED DESCRIPTION OF EMBODIMENTS

**[0033]** Figure 1 shows two adjacent cabins 10, 12 of a passenger ship. Each cabin 10, 12 has a toilet 14, 16. Conditioned air from a centrally located air-handling unit 21 enters each cabin via an air terminal device 18, 20. Each air terminal device 18, 20 is located near the ceiling of the toilet and ventilates the cabin space via a grille 22, 24 at the top of the toilet frame. Usually a fixed amount of exhaust air exits the cabin space via an air valve in the toilet connected to an exhaust duct system 19 usually exiting to the atmosphere. The balance of the air supplied to the cabin, enters the corridor 26 via vents in the door or walls of the cabin where it is exhausted via a duct system 28 back to the air-handler. The duct 28 is for example a rectangular sheet steel duct with thermal insulation on the inside.

**[0034]** Figure 2 shows a device according to an embodiment of the invention. The device comprises a duct that may or may not be housed within an air terminal casing 28 having an air inlet 30 and two air outlets 32 located on opposite sides of the duct 28. In the illustrated example the air inlet 30 receives pressurized conditioned air from an air-handler 21 and the air outlets 32 supply conditioned air to a cabin. The dashed arrows show the direction of air flow through the duct 28. The duct 28 in the illustrated embodiment also comprises a heat exchanger 34 to heat or cool the air passing through it. The inventive device includes a slide damper that comprises a slidably mounted plate 36 that is arranged to slide over and at least partially cover both of the two air outlets 32. According to an embodiment of the invention the device could include two separate slidably mounted plates; one to cover each air outlet.

**[0035]** When the air outlets 32 are fully closed by the slidably mounted plate 36 a substantially air-tight seal is obtained. The flow of air may be started, stopped or regulated by the slidably mounted plate 36 that opens, closes or partially obstructs the two air outlets 32. In the fully open position the air outlet cross sectional area is A. The cross sectional area of the air outlet at every other damper position, which is known at all times, may be determined experimentally or mathematically. The slide damper may be used constantly, periodically, on request or in case of an emergency only. Perforated flow diverting plates 33 are arranged to guide air out of the air outlets 32 into the cabin.

**[0036]** The device comprises means to measure the pressure ($p_1$) of air upstream of the damper and means to measure the pressure ($p_2$) of air downstream of the damper. Said pressures ($p_1$ and $p_2$) are preferably measured at positions where the air flow is not too turbulent by means of a manometer, mechanical pressure guage, electromechanical sensor, strain guage, piezoelectric pressure transducer or any other suitable means. The flow (Q) of air being supplied to the cabin is calculated using the cross sectional area (A) of the air outlets 32 and the pressure measurements $p_1$ and $p_2$. If the flow rate needs to be changed because it does not correspond to a desired flow rate, the slidably mounted plate 36 is displaced by a known amount using actuation means. The actuation means in the illustrated embodiment comprises a step motor 38 that receives pulses from an electronic control unit and drives a screw 40 or compresses/expands resilient means, such as a spring, which consequently displaces the displaceable element 36 by a predetermined and exact amount in accordance with the number of pulses received.

**[0037]** Figure 3 is a flow diagram showing a method according to an embodiment of the invention. The method comprises the steps of determining the cross sectional area of the air outlets and the pressure of air upstream of the damper ($p_1$) and the pressure of air downstream of the damper ($p_2$). The air flow (Q) is then calculated and the position of the slidably mounted plate is adjusted if the air flow (Q) does not correspond to the desired air flow ($Q_{desired}$) whereupon the process may be repeated.

**[0038]** Figure 4 shows a perspective view of a duct 28 comprising an air outlet 32 in and a slidably mounted plate 36 according to an embodiment of the invention.

**[0039]** Figure 5 shows a displaceable element 36 that comprises at two opposing gates 42 and 44 whereby a gate 42 is arranged to open, partly obstruct or close an air outlet 32.

**[0040]** Further modifications of the invention within the scope of the claims would be apparent to a skilled person. For example, the inventive device and method are suitable for the regulation of any fluid, i.e. any liquid or gas, not only air.

**Claims**

1. Device for regulating the flow (Q) of air supplied to an isolated cell (10,12) comprising a duct (28) having an air inlet (30) and two air outlets (32) located on opposite sides/parts of the duct (28) or a plurality of such pairs of outlets (32), a damper that comprises a displaceable element (36) that is arranged to move

over said at least two air outlets (32) in order to adjust the cross sectional area (A) of said at least two air outlets (32), means to determine the pressure of air upstream of the damper ($p_1$), means to determine the pressure of air downstream of the damper ($p_2$), means to determine the cross sectional area (A) of said at least two outlets (32), means to calculate the air flow (Q) or pressure that is supplied to the isolated cell (10,12) through said at least two outlets (32) of the duct (28) and actuation means (38,40) to displace the displaceable element (36) in order to obtain a desired air flow, **characterized in that** the displaceable element (36) comprises two opposing gates whereby one of said gates (42) is arranged to open, partly obstruct or close one or more air outlets (32) located on one side/part of the duct (28) and the other gate (44) is arranged to open, partly obstruct or close one or more air outlets (32) located on the opposing side/part of the duct (28) in order to achieve the desired air flow.

**2.** Device according to claim 1, **characterized in that** it comprises vortex reducing means to break up large flow induced vortices into smaller vortices, such as at least one perforated plate, located downstream of said at least two air outlets.

**3.** Device according to claim 1 or 2, **characterized in that** it comprises air flow diverting means located downstream of said at least two air outlets (32) to direct the air flow in a particular direction.

**4.** Device according to any of the preceding claims, **characterized in that** the thickness of said two opposing gates (42, 44) is less than 5mm, preferably less than 3mm and most preferably less than 2mm.

**5.** Device according to any of the preceding claims, **characterized in that** said displaceable element (36) is a slideably, pivotably or rotatably mounted element.

**6.** Device according to any of the preceding claims, **characterized in that** it comprises actuation means (38, 40) to displace the displaceable element (36) manually or automatically whereby said actuation means are responsive to an output of a sensor or control unit that is indicative of the desired air flow or pressure.

**7.** Device according to any of the preceding claims, **characterized in that** said actuation means comprise a motor (38) and a control linkage.

**8.** Ventilation system for ventilating at least one isolated cell (10,12), **characterized in that** it comprises a device according to any of the preceding claims.

**9.** Ventilation system according to claim 8, **characterized in that** said at least one isolated cell (10,12) comprises an air inlet vent and an air exhaust vent and that an air supply regulating device is mounted in the vicinity of said air inlet and/or air exhaust.

**10.** Ventilation system according to claim 8 or 9, **characterized in that** it comprises means (34) to heat and/or cool the air supplied to said at least one isolated cell (10,12) and means to regulate the temperature of said at least one isolated cell by air flow control.

**11.** Method for regulating the flow (Q) or pressure of air supplied to an isolated cell (10,12) through a duct (28) that comprises a damper, whereby the duct comprises an air inlet (30) and two air outlets (32) located on opposite sides/parts of the duct (28) or a plurality of such pairs of outlets (32), which comprises the steps of determining the pressure of air upstream of the damper ($p_1$), determining the pressure of air downstream of the damper ($p_2$), determining the cross sectional area (A) of said at least two air outlets (32), calculating the air flow (Q) or pressure supplied by the duct (28) and **characterized in that** it comprises the step of adjusting the cross sectional area (A) of said at least two air outlets (32) by displacing an element (36) that comprises two opposing gates (42, 44) whereby one of said gates (42) is arranged to open, partly obstruct or close one or more air outlets (32) located on one side/part of the duct (28) and the other gate (44) is arranged to open, partly obstruct or close one or more air outlets (32) located on the opposing side/part of the duct (28) in order to achieve the desired air flow.

**12.** Method according to claim 11, **characterized in that** it comprises the step of actuating the displaceable element (36) automatically on receiving a signal from a sensor or control unit which is indicative of the desired air flow or pressure.

**13.** Method according to claim 12, **characterized in that** it comprises the step of regulating the air flow so that the flow of air supplied to the isolated cell (10,12) substantially corresponds to the flow of air exhausted from the isolated cell (10,12).

**14.** Method according to any of claims 11-13, **characterized in that it** comprises the step of heating and/or cooling the air supplied to the isolated cell (10,12) and regulating the temperature of the isolated cell by air flow control.

**15.** Computer program product, **characterized in that** it comprises a computer program containing computer program code means arranged to cause a computer or a processor to execute at least one of the

steps of a method according to any of claims 11-14, stored on a computer-readable medium or a carrier wave.

**16.** Electronic control unit (ECU), **characterized in that** it comprises a computer program product according to claim 15.

**17.** Sea-going vessel, such as a passenger ship or other movable or fixed offshore installation that is divided into a plurality of isolated cells, such as cabins (10,12), **characterized in that** it comprises a device according to any of claims 1-7 or a ventilation system according to any of claims 8-10 or an ECU according to claim 16 or **in that** it utilizes a method according to any of claims 11-14.

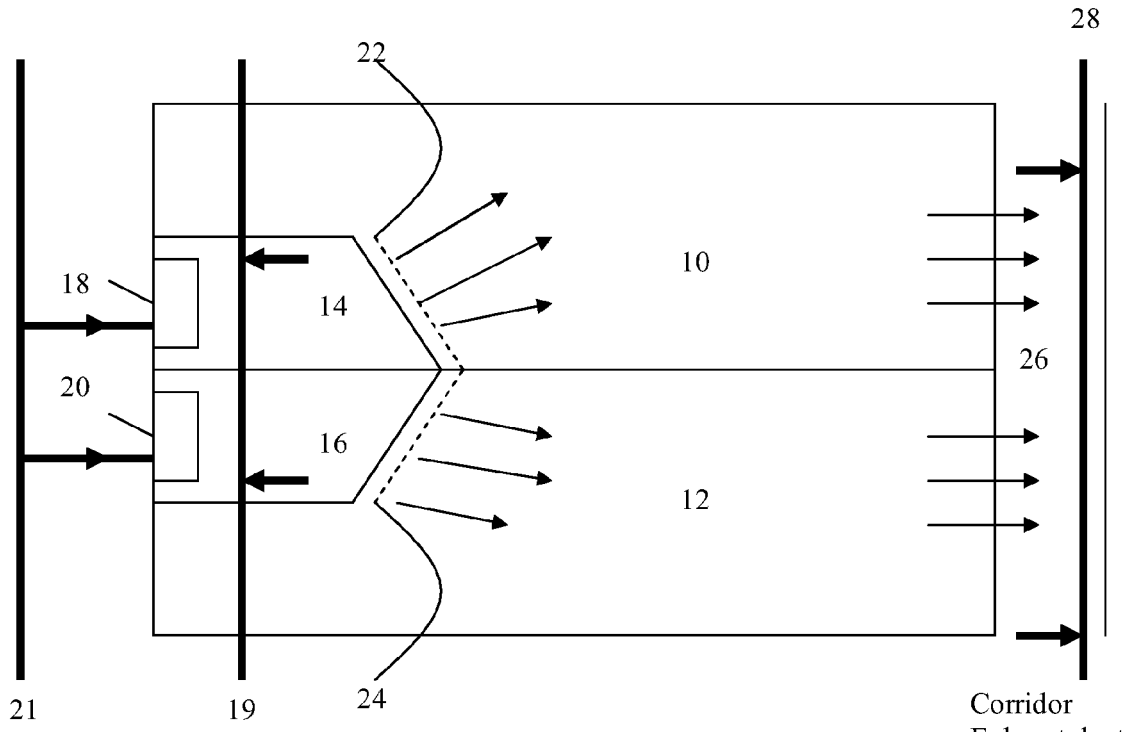

28
22
18
14
10
26
20
16
12
21
19
24
Corridor
Exhaust duct

Fig. 1

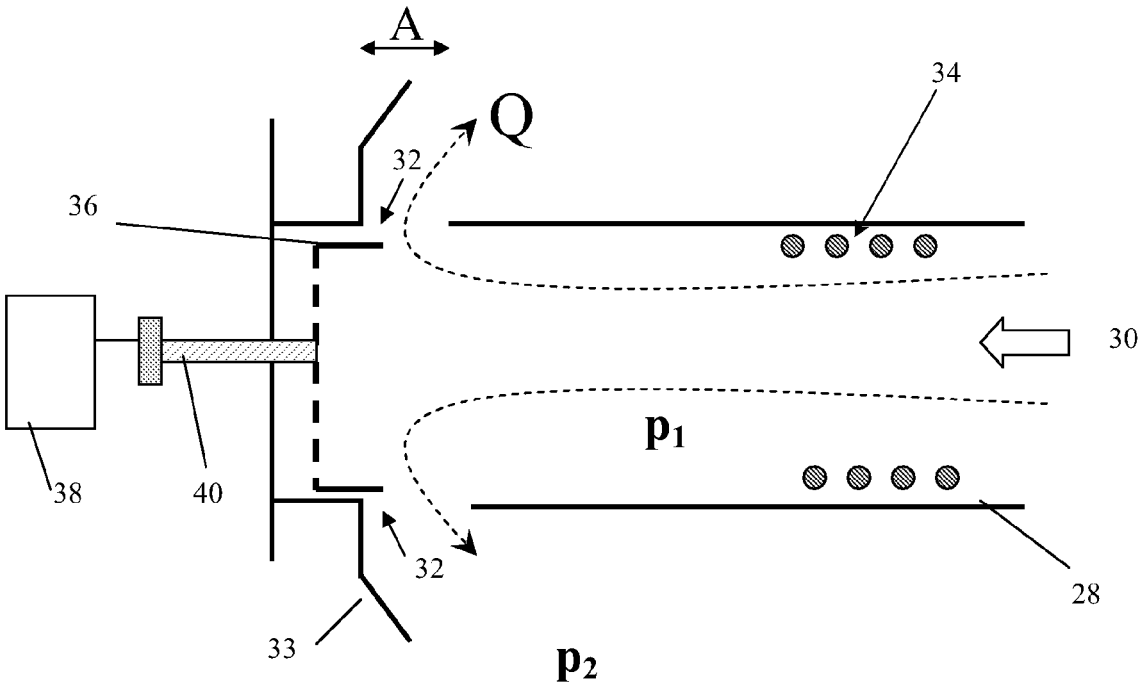

A
Q
34
32
36
30
p1
38
40
32
28
33
p2

Fig. 2

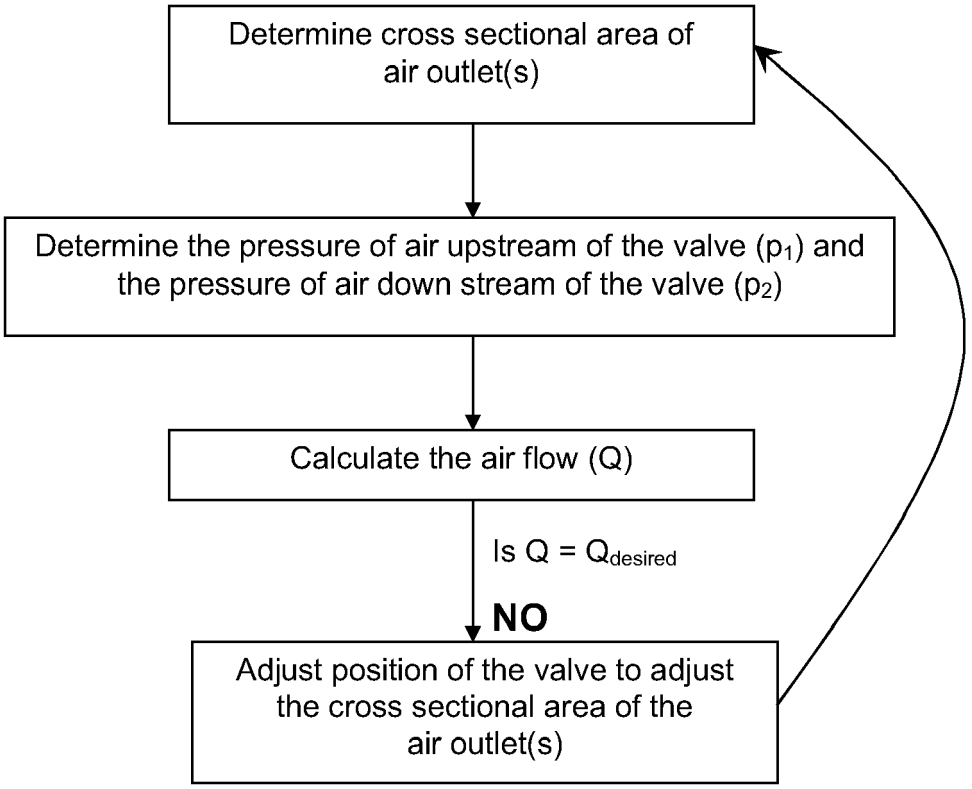

Determine cross sectional area of air outlet(s)
Determine the pressure of air upstream of the valve ($p_1$) and the pressure of air down stream of the valve ($p_2$)
Calculate the air flow (Q)
Is Q = $Q_{desired}$
NO
Adjust position of the valve to adjust the cross sectional area of the air outlet(s)

Fig. 3

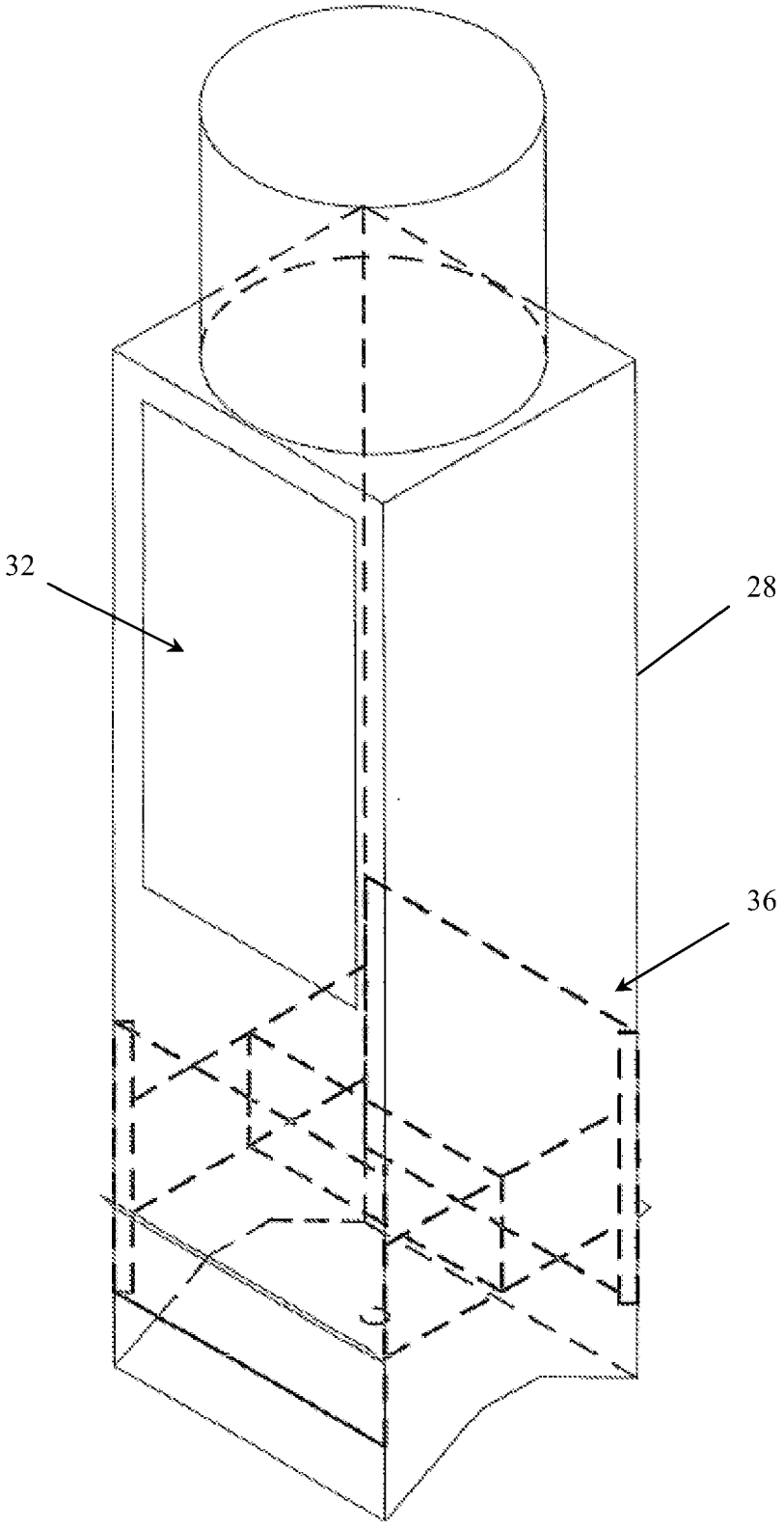



Fig. 4

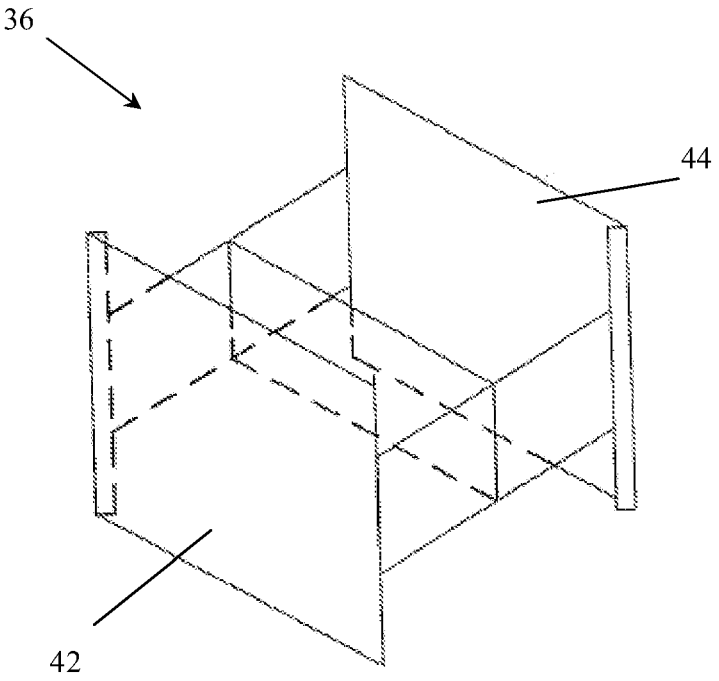



Fig. 5

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- SE 510211 **[0007]**