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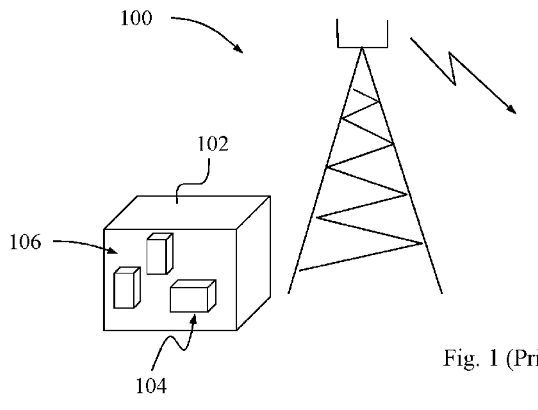

Fig. 1 (Prior art)

(57) **Abstract**: An apparatus for ventilation of an enclosure (300) in which a battery is housed, comprising a partition (302) separating the enclosure from ambient air and comprising an orifice (302a), and a valve member (304) extending through the orifice to form a variable air gap (306) for ventilation of the enclosure. The apparatus also comprises an air conveying device (308) arranged to create a pressure (P_1) inside the partition which is different than a pressure (P_0) outside the partition such that air flows through the air gap. One of the partition and the valve member is movable against a counteracting force so as to regulate the air gap in response to variations of the pressure inside the partition. Thereby, a substantially uniform air flow is maintained through the air gap regardless of the current operating capacity of the air conveying device.

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APPARATUS FOR VENTILATION OF ENCLOSURE WITH BATTERY

Technical field

The present disclosure relates generally to an apparatus for ventilation of an enclosure in which a battery is housed, and to a cabinet comprising the apparatus.

Background

Batteries used for power supply to electronic equipment typically emit hydrogen gas which may form an explosive gas mix together with air. This mix of hydrogen gas and air may thus explode if a spark occurs, e.g. caused by operating the electronic equipment or by moving machine parts or the like, if present. When a battery is housed within an enclosure, e.g. formed by a cabinet, container, box or similar, prevailing safety regulations often require that the enclosure is continuously ventilated to some extent by ambient air. This is to avoid that harmful amounts of hydrogen gas emitted by the battery are accumulated over time inside the enclosure which would otherwise gradually increase the risk for explosion.

Such enclosures housing batteries typically also house electronic equipment that can be powered by the battery. An illustrative example of this is equipment for telecommunication which may reside at various network nodes such as base stations, switches, routers, gateways, and so forth. Fig. 1 illustrates an exemplifying base station 100 used for radio communication with wireless devices, not shown. The base station 100 comprises a cabinet or the like forming an enclosure 102 in which a battery 104 is housed together with various electronic equipment 106 such as transceivers and power amplifiers.

The electronic equipment 106 typically generates heat, more or less, and needs to be cooled so as to operate within a desired temperature range. In order to achieve proper cooling, a fan or the like, not shown, is typically installed in the enclosure 102, operating to convey air within and thus create a cooling air flow over the electronic equipment 106. In order to achieve ventilation of the enclosure 102 as well, that is to discharge hydrogen gas from the enclosure when emitted by the battery, the enclosure 102 can be provided with one or more air openings so that ambient air can be drawn into and discharged from the enclosure by the fan.

Thereby, both cooling and ventilation can be accomplished by the fan. Another way of achieving cooling is to employ some heat exchanger and/or active cooling elements on the heat generating equipment, which is however costly to install and maintain.

Furthermore, the need for cooling may change over time depending on how much heat is generated by the electronic equipment 106 and also depending on variations of the ambient temperature. For example, if several transceivers and power amplifiers are operating intensely during periods of heavy radio traffic they will generate more heat as compared to periods of low radio traffic. Another example is that electronic equipment may be added or removed within the same enclosure which also creates variations in the amounts of heat generated. In order to achieve proper cooling in either situation, the fan is typically regulated automatically so as to operate with variable capacity, e.g. speed of the fan, depending on the amount of heat currently generated.

However, if excessive amounts of ambient air are allowed to enter the enclosure 102, e.g. when the fan is operating with high capacity, the electronic equipment 106 may be damaged since the ambient air is typically humid and contains certain amounts of dirt, dust, salt and moisture, etc., which thus may result in damage or improper operation of the electronic equipment. This may be overcome, at least partly, e.g. by employing air filters and/or heat exchangers with active cooling by compressors, and so forth. On the other hand, such arrangements are costly to install and maintain, e.g. by cleaning filters and regulating the heat exchange. If a fan with variable operating capacity is employed to control the cooling effect, the ventilation may be insufficient to eliminate the risk for explosion during periods of low equipment activity and resulting low fan speed, or conversely the electronic equipment and/or the battery itself may be impaired by too much contaminated ambient air coming into the enclosure.

<u>Summary</u>

It is an object of embodiments described herein to address at least some of the problems and issues outlined above. It is possible to achieve this object and others by using an apparatus and a cabinet as defined in the attached independent claims.

According to one aspect, an apparatus is provided for ventilation of an enclosure in which a battery is housed. The apparatus comprises a partition separating the enclosure from ambient air and comprising an orifice. The apparatus also comprises a valve member extending through the orifice to form a variable air gap for ventilation of the enclosure, and an air conveying device arranged to create a pressure inside the partition which is different than a pressure outside the partition such that air flows through the air gap. In this apparatus, one of the partition and the valve member is movable against a counteracting force so as to regulate the air gap in response to variations of the pressure inside the partition such that a substantially uniform air flow is maintained through the air gap.

Thereby, a substantially uniform air flow can be maintained through the air gap also when the current operating capacity of the air conveying device changes which causes the variations of the pressure inside the partition. The above apparatus may be configured and implemented according to different optional embodiments to accomplish further features and benefits, to be described below.

According to another aspect, a cabinet is provided which comprises a battery, an electronic equipment, and the apparatus according to any of the embodiments described herein, wherein the air conveying device is arranged to create an airflow for cooling or heating the electronic equipment.

Brief description of drawings

The solution will now be described in more detail by means of exemplary embodiments and with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of a cabinet housing a battery and electronic equipment for a base station, according to the prior art.

Fig. 2 is a block diagram illustrating a cabinet comprising an apparatus for ventilation of an enclosure, in which at least some embodiments may be used.

Fig. 3 is a section view of a first example of an apparatus for ventilation of an enclosure, according to some possible embodiments.

Fig. 4 is a section view of a second example of an apparatus for ventilation of an enclosure, according to further possible embodiments.

Fig. 5 is a section view of a third example of an apparatus for ventilation of an enclosure, according to further possible embodiments.

Fig. 6 is a section view of a fourth example of an apparatus for ventilation of an enclosure, according to further possible embodiments.

Fig. 7 is a diagram illustrating variations of air flow depending on a differential pressure dP in two cases when the solution is used and not used, respectively.

Fig. 8 is a diagram illustrating various forces in action in an apparatus for ventilation of an enclosure, when at least some embodiments are employed.

Figs 9, 10a-c and 11 are section views illustrating different examples of how the apparatus for ventilation of an enclosure may be realized in practice, according to further possible embodiments.

Detailed description

A solution is provided which can be used to avoid the above-described situations of insufficient and excessive ventilation of an enclosure in which a battery is housed and where an air conveying device with variable operating capacity, such as a fan, is used for making ambient air coming into the enclosure for ventilation. This can be achieved by an apparatus comprising a self-regulating valve function balanced by a differential pressure which creates a substantially uniform flow of air entering the enclosure, as follows.

The block diagram in Fig. 2 illustrates a cabinet 200 comprising an apparatus for ventilation of an enclosure 200a, being an example where this solution may be used. In this enclosure 200a, a battery 202 and some electronic equipment 204 are housed. The battery 202 may be used for powering the electronic equipment 204, either as back-up or main power supply. The electronic equipment 204 may be used for operating a node of a telecommunication network such as a base station, although the solution is not limited to any particular type of electronic equipment 204. The battery 202 may emit hydrogen gas such that the enclosure needs to be ventilated for reasons explained above. The enclosure 200a also contains a fan or the like, hereafter referred to as an air conveying device 206, which operates to cool the electronic equipment 204 by conveying or moving air inside the enclosure 200a, which is schematically illustrated by arrows.

The air conveying device 206 basically operates to create a low pressure side where air is drawn into the device 206 and a high pressure side where the air is blown out from the device 206, as schematically indicated by a dashed dividing line, thereby causing movement of the air inside the enclosure 200a for cooling the equipment 204. A dividing wall or the like may be arranged in the enclosure 200a to separate the low pressure side and the high pressure side.

In order to achieve the desired ventilation, air must also leave the enclosure 200a and be replaced by ambient air to some extent. This is achieved by the enclosure 200a having an air inlet 208 at the low pressure side and an air outlet 210 at the high pressure side. It should be noted that the inlet 208 and outlet 210 are illustrated schematically in this figure and they may in practice be realized as one or several openings through the cabinet 200. For example, a duct or pipe may be arranged as the air outlet to be close to the battery, while the air inlet may be accomplished by multiple small chinks or the like commonly occurring in cabinet structures, or vice versa. It is also possible to reverse operation of the air conveying device 206 such that the inlet 208 becomes an air outlet 208 and the outlet 210 becomes an air inlet 210, thus switching the high and low pressure sides.

Briefly described, the above-mentioned self-regulating valve function is achieved by an apparatus comprising a partition with an orifice and a valve member extending through the orifice, the apparatus being arranged in either of the outlet and inlet 208, 210. Either of the partition and the valve member is movable so as to create a variable air gap between the valve member and the orifice for ventilation of the enclosure 200a, such that the air gap is dependent on variations of the pressure inside the partition caused by the air conveying device.

The solution may thus be realized as an apparatus for ventilation of an enclosure in which a battery is housed. The apparatus comprises a partition separating the enclosure from ambient air and having an orifice, and a valve member extending through the orifice to form a variable air gap for ventilation of the enclosure. The apparatus also comprises an air conveying device arranged to create a pressure inside the partition which is different than a pressure outside the partition such that air flows through the air gap. In this arrangement, one of the partition and the valve member is movable against a counteracting force so as to regulate the air gap in response to variations of the pressure inside the partition, such that a substantially uniform air flow can be maintained through the air gap. Thereby, a self-regulating valve function is accomplished so as to avoid both insufficient and excessive ventilation of the enclosure.

Figs 3-6 illustrate some examples of how this apparatus and the above-mentioned components and features may be realized, according to different possible embodiments.

A first example of how the apparatus can be implemented in an air inlet, e.g. the inlet 208 in Fig. 2, will now be described with reference to Fig. 3. In this figure, an enclosure 300 is schematically illustrated in which a battery, not shown, is housed. Further, various electronic equipment may also be housed in the enclosure 300, although not shown here either for simplicity. The apparatus comprises a partition 302 separating the enclosure 300 from ambient air. The partition 302 comprises an orifice 302a which may be an opening through the partition 302 of circular shape or any other shape. The apparatus also comprises a valve member 304 extending through the orifice 302a to form an air gap 306 for ventilation of the enclosure. The air gap 306 is variable when the partition 302 and the valve member 304 are displaced relative one another.

The apparatus further comprises an air conveying device 308 arranged to create a pressure P_1 inside the partition 302 which is different than an ambient pressure P_0

outside the partition 302, such that air flows through the air gap 306 due to this difference in pressures, also referred to as the differential pressure. In this case, the air conveying device 308 is arranged to draw ambient air through the inlet into the enclosure 300 so that $P_1 < P_0$. The resulting air flow in this example is indicated by white arrows.

In a possible embodiment according to this example, the valve member 304 is fixedly attached to the enclosure 300 and the partition 302 is flexibly attached to the enclosure 300 so as to be movable relative the valve member 304 against a counteracting force when the pressure P_1 inside the partition is changed. For example, the partition may be made movable by comprising a circumferential flexible membrane attached to the enclosure 300.

In another possible embodiment, at least one spring 310 is arranged between the partition 302 and the enclosure 300 so as to create the counteracting force. The spring 310 may be comprised of one or more coil springs or any other useful type of spring. Thereby, the partition 302 is movable against the counteracting force created by the spring 310, as indicated by two-way arrows. Alternatively, the counteracting force may be created by the weight of the movable partition 302 if the apparatus is oriented so that the partition 302 is movable substantially upwards and downwards.

Since $P_1 < P_0$, the partition 302 is subjected to a pressure force in a direction inwards to the enclosure, i.e. to the left in this figure, which is balanced by the counteracting force created by the spring 310, i.e. when acting in the opposite right direction. When the pressure P_1 inside the partition 302 is changed due to changed operating capacity of the air conveying device 308, the partition 302 will move so that the air gap 306 is adjusted accordingly and the same air flow is substantially maintained through the air gap 306.

In more detail, when the air conveying device 308 operates with increased operating capacity, e.g. when the rotation speed of a fan is increased to increase the cooling effect, the partition 302 will move to the left in this example and the air gap 306 will be reduced so as to maintain the same air flow despite the increased operating capacity of the air conveying device 308. On the other hand, when the air conveying device 308 operates with reduced operating capacity when the cooling need decreases, the partition 302 will move to the right and the air gap 306 will be opened so as to maintain the same air flow through the air gap 306. Hence, the self-regulating valve function is automatically created by the fixed valve member 304 and the movable partition 302.

Fig. 3 further illustrates schematically that the enclosure 300 has an air inlet 312 and an air outlet 314. As said above, the apparatus in this example is installed in the air inlet 312 of the enclosure 300. In another possible embodiment, when the valve member 304 is fixedly attached to the enclosure 300, the valve member 304 may comprise a tapered element having a narrow section arranged substantially outside the partition 302 and a wide section arranged substantially inside the partition 302, as shown in Fig. 3. Thereby, the air gap 306 will be reduced when the pressure P_1 inside the partition 302 is decreased to increase the differential pressure thus moving the partition 302 to the left, while the air gap 306 will be opened when the pressure P_1 is increased to decrease the differential pressure thus moving the partition 302 to the right.

A second example of how the apparatus can be implemented in an air inlet, will now be described with reference to Fig. 4. As in the previous example, an enclosure 400 is housing a battery and possibly also housing various electronic equipment, not shown. The apparatus comprises a partition 402 having an orifice 402a, and also a valve member 404 extending through the orifice 402a to form an air gap 406 for ventilation of the enclosure. The air gap 406 is variable when the partition 402 and the valve member 404 are moved relative one another.

The apparatus further comprises an air conveying device 408 arranged to create a pressure P_1 inside the partition 402 which is different than an ambient pressure P_0 outside the partition 402, such that air flows through the air gap 406 due to the differential pressure. Also in this case, the air conveying device 408 is arranged to draw ambient air through the inlet into the enclosure 400 so that $P_1 < P_0$. The resulting air flow in this example is therefore the same as in Fig. 3, as indicated by white arrows.

In a possible embodiment according to the example in Fig. 4, the partition 402 is fixedly attached to the enclosure while the valve member 404 is flexibly attached to the enclosure 400 so as to be movable relative the partition 402 when the pressure P_1 inside the partition is changed.

In another possible embodiment, at least one spring 410 is arranged between the valve member 404 and the enclosure 400 so as to create the counteracting force. The spring 410 may be comprised of one or more coil springs or any other type of springs. Thereby, the valve member 404 is movable against the counteracting force created by the spring 410, as indicated by a two-way arrow. Alternatively, the counteracting force may be created by the weight of the movable valve member 404 if the apparatus is oriented so that the valve member 404 is movable substantially upwards and downwards.

Since $P_1 < P_0$, the valve member 404 is subjected to a pressure force in a direction inwards to the enclosure 400, i.e. to the left in the figure, which is balanced by the counteracting force created by the spring 410, i.e. when acting in the opposite right direction. When the pressure P_1 is changed due to changed operating capacity of the air conveying device 408, the valve member 404 will move relative the partition 402 so that the air gap 406 is adjusted accordingly and the same air flow is substantially maintained through the air gap 406.

In more detail, when the air conveying device 408 operates with increased operating capacity, e.g. when the rotation speed of a fan is increased to increase the cooling effect, the valve member 404 will move to the left in this example and the air gap 406 will be reduced so as to maintain the same air flow despite the increased operating capacity of the air conveying device 408. On the other hand, when the air conveying device 408 operates with reduced operating capacity when the cooling need decreases, the valve member 404 will move to the right and the air gap 406 will be opened so as to maintain the same air flow through the air gap

406. Hence, the self-regulating valve function is automatically created in this example by the fixed partition 402 and the movable valve member 404.

Fig. 4 further illustrates schematically that the enclosure has an air inlet 412 and an air outlet 414. As said above, the apparatus in this example is installed in the air inlet 412 of the enclosure 400. In another possible embodiment, when the valve member 404 is flexibly attached to the enclosure 400, the valve member 404 may comprise a tapered element having a narrow section arranged substantially inside the partition 402 and a wide section arranged substantially outside the partition 402, as shown in Fig. 4. Thereby, the air gap 406 will be reduced when the pressure P_1 inside the partition 402 is decreased to increase the differential pressure thus moving the valve member 404 to the left, while the air gap 406 will be opened when the pressure P_1 is increased to decrease the differential pressure thus moving the valve member 404 to the right.

In the examples of Figs 3 and 4, the apparatus was installed in an air inlet 312, 412 of the enclosure 300, 400 and the air conveying device 308, 408 was arranged to draw ambient air into the enclosure 300, 400 so that $P_1 < P_0$. In other embodiments, it is also possible that the apparatus is configured to be installed in an air outlet of the enclosure, and the air conveying device may be arranged to blow air out from the enclosure so that the air flow has an opposite direction as compared to Figs 3 and 4. Two examples of how the apparatus may be implemented in such circumstances will now be described with reference to Figs 5 and 6.

A first example of how the apparatus can be implemented in an air outlet, will now be described with reference to Fig. 5. As in the previous examples, an enclosure 500 is housing a battery and possibly also various electronic equipment, not shown. The apparatus comprises a partition 502 having an orifice 502a, and also comprises a valve member 504 extending through the orifice 502a to form an air gap 506 for ventilation of the enclosure. The air gap 506 is variable when the partition 502 and the valve member 504 are moved relative one another.

The apparatus further comprises an air conveying device 508 arranged to create a pressure P_2 inside the partition 502 which is different than an ambient pressure P_0 outside the partition 502, such that air flows through the air gap 506 due to the differential pressure. In this case, the air conveying device 508 is thus arranged to blow air through the outlet out from the enclosure 500 so that $P_2 > P_0$. The resulting air flow in this example is therefore opposite from the examples of Figs 3 and 4, as indicated by white arrows.

In the example in Fig. 5, the valve member 504 is fixedly attached to the enclosure 500 and the partition 502 is flexibly attached to the enclosure 500 so as to be movable relative the valve member 504 against a counteracting force when the pressure P_1 inside the partition is changed. As in the example of Fig. 3, at least one spring 510 is arranged between the partition 502 and the enclosure 500 so as to create the counteracting force. The spring 510 may be comprised of one or more coil springs or any other type of springs. Thereby, the partition 502 is movable against the counteracting force created by the spring 510, as indicated by two-way arrows. Alternatively, the counteracting force may be created by the weight of the movable partition 502 if the apparatus is oriented so that the partition 502 is movable substantially upwards and downwards.

Since $P_2 > P_0$, the partition 502 is subjected to a pressure force in a direction outwards from the enclosure 500, i.e. to the right in the figure, which is balanced by the counteracting force created by the spring 510, i.e. when acting in the opposite left direction. When the pressure P_2 is changed due to changed operating capacity of the air conveying device 508, the partition 502 will move relative the valve member 504 so that the air gap 506 is adjusted accordingly and the same air flow is substantially maintained through the air gap 506.

In more detail, when the air conveying device 508 operates with increased operating capacity, e.g. when the rotation speed of a fan is increased to increase the cooling effect, the partition 502 will move to the right in this example and the air gap 506 will be reduced so as to maintain the same air flow despite the increased operating capacity of the air conveying device 508. On the other hand, when the air conveying device 508 operates with reduced operating capacity when the cooling need decreases, the partition 502 will move to the left and the air gap 506 will be opened so as to maintain the same air flow through the air gap 506. Hence, the self-regulating valve function is automatically created in this example by the fixed valve member 504 and the movable partition 502.

Fig. 5 further illustrates schematically that the enclosure 500 has an air outlet 512 and an air inlet 514. As said above, the apparatus in this example is installed in an air outlet 512 of the enclosure 500. In another possible embodiment, when the valve member 504 is fixedly attached to the enclosure 500, the valve member 504 may comprise a tapered element having a narrow section arranged substantially inside the partition 502 and a wide section arranged substantially outside the partition 502, as shown in Fig. 5. Thereby, the air gap 506 will be reduced when the pressure P_2 inside the partition 502 is increased to increase the differential pressure thus moving the partition 502 to the right, while the air gap 506 will be opened when the pressure P_2 is decreased to decrease the differential pressure thus moving the partition 502 to the left.

A second example of how the apparatus can be implemented in an air outlet, will now be described with reference to Fig. 6. As in the previous examples, an enclosure 600 is housing a battery and possibly also various electronic equipment, not shown. The apparatus comprises a partition 602 having an orifice 602a, and also a valve member 604 extending through the orifice 602a to form an air gap 606 for ventilation of the enclosure 600. The air gap 606 is variable when the partition 602 and the valve member 604 are moved relative one another.

The apparatus further comprises an air conveying device 608 arranged to create a pressure P_2 inside the partition 602 which is different than an ambient pressure P_0 outside the partition 602, such that air flows through the air gap 606 due to the differential pressure. As in Fig. 5, the air conveying device 608 is thus arranged to blow air out through the outlet from the enclosure 600 so that $P_2 > P_0$. The resulting air flow in this example is therefore the same as in Fig. 5 but opposite from the examples of Figs 3 and 4, as indicated by white arrows.

In a possible embodiment according to the example in Fig. 6, the partition 602 is fixedly attached to the enclosure 600 while the valve member 604 is flexibly attached to the enclosure 600 so as to be movable relative the partition 602 when the pressure P_2 inside the partition is changed.

In another possible embodiment, at least one spring 610 is arranged between the valve member 604 and the enclosure 600 so as to create the counteracting force. The spring 610 may be comprised of one or more coil springs or any other type of springs. Thereby, the valve member 604 is movable against the counteracting force created by the spring 610, as indicated by a two-way arrow. Alternatively, the counteracting force may be created by the weight of the movable valve member 604 if the apparatus is oriented so that the valve member 604 is movable substantially upwards and downwards.

Since $P_2 > P_0$, the valve member 604 is subjected to a pressure force in a direction outwards from the enclosure 600, i.e. to the right in the figure, which is balanced by the counteracting force created by the spring 610, i.e. when acting in the opposite left direction. When the pressure P_2 is changed due to changed operating capacity of the air conveying device 608, the valve member 604 will move relative the partition 602 so that the air gap 606 is adjusted accordingly and the same air flow is substantially maintained through the air gap 606.

In more detail, when the air conveying device 608 operates with increased operating capacity, e.g. when the rotation speed of a fan is increased to increase the cooling effect, the valve member 604 will move to the right in this example and the air gap 606 will be reduced so as to maintain the same air flow despite the increased operating capacity of the air conveying device 608. On the other hand, when the air conveying device 608 operates with reduced operating capacity when the cooling need decreases, the valve member 604 will move to the left and the air gap 606 will be opened so as to maintain the same air flow through the air gap 606. Hence, the self-regulating valve function is automatically created in this example by the fixed partition 602 and the movable valve member 604.

Fig. 6 further illustrates schematically that the enclosure 600 has an air outlet 612 and an air inlet 614. As said above, the apparatus in this example is installed in the air outlet 612 of the enclosure 600. In another possible embodiment, when the valve member 604 is flexibly attached to the enclosure 600, the valve member 604 may comprise a tapered element having a narrow section arranged substantially outside the partition 602 and a wide section arranged substantially inside the partition 602, as shown in Fig. 6. Thereby, the air gap 606 will be reduced when the pressure P_2 inside the partition 602 is increased to increase the differential pressure thus moving the valve member 604 to the right, while the air gap 606 will be opened when the pressure P_2 is decreased to decrease the differential pressure thus moving the valve member 604 to the left.

In the examples of Figs 3-6, the valve member 304, 404, 504, 604 is schematically shown to have a tapered shape which means that the air gap changes at relative movement or displacement between the valve member and the partition 302, 402, 502, 602 in the manner described above. For example, the tapered shape may be substantially conical so that the air gap is variable in a linear manner. However, any other tapered shapes are also possible, e.g. so that the air gap is variable in an exponential or step-like manner, and the solution is not limited to any particular tapered shape. It is also possible to use a tapered shape of the orifice 302a, 402a, 502a, 602a. Thus, at least one of the valve member 304, 404, 504, 604 and the orifice 302a, 402a, 502a, 602a may have a tapered shape so as to accomplish the variable air gap.

The diagram in Fig. 7 illustrates measurements of how the air flow, coming into and out from an enclosure with a battery, varies with the differential pressure “dP”,which represents the difference in pressure outside and inside the enclosure, in two different cases as follows. A first curve 700 shows measurements of the air flow for the case where an air gap of fixed size is employed for ventilation of the enclosure according to conventional solutions, i.e. the self-regulating valve function described herein is not employed. It can be seen that the air flow cannot be maintained constant but steadily increases with increased differential pressure dP which is created by a variable air conveying device in the enclosure. Thereby, the above-described problems with insufficient or excessive ventilation cannot be avoided.

In contrast thereto, a second curve 702 shows measurements of the air flow for the case where an air gap of variable size is employed for ventilation of the enclosure according to any of the embodiments described herein, i.e. when the above-described self-regulating valve function is employed. It can be seen that the same, or constant, air flow is substantially maintained across a large range of the differential pressure dP increases, thus when the air conveying device is operated with different capacities, such that the problems with insufficient or excessive ventilation can be avoided or at least reduced.

It was described above that one of the partition and the valve member is movable against a counteracting force, which may be created by a spring-like element. The differential pressure acts as one force on the movable part, either the partition or the valve member, while the spring acts as another opposite force, i.e. the above-described counteracting force. When the two forces are in balance, the movable part is in a certain position along its direction of movement, thus allowing an air flow through the above-described air gap.

The spring constant, the area subjected to the differential pressure and the air gap´s size are balanced by the pressure difference between the inside of the partition and the ambient air outside the partition. Fig. 8 illustrates the forces acting on the movable part when the pressure inside the partition is P_x and the pressure outside the partition is P_y.

The forces in action include the following:

The counteracting force “FS” created by the spring is: FS = k * dx

where k = spring constant factor according to Hooks law, and
dx = displacement of the movable part.

The force “FP” created by the pressure difference is: FP = dP * AP

Where dP is the differential pressure dP = P_y - P_x, and
AP = Area of the movable part being subjected to the differential pressure.

Fig. 8 shows that the forces Fs and Fp can be in balance, i.e. equal, when a certain displacement dx of the movable part and resulting size of the area AP occur.

The air flow through the air gap may depend on how the air gap is designed, and what pressure difference is applied across the air gap's inlet and outlet. This differential pressure may be equal to the differential pressure dP as defined above, but it may also be different, therefore it is denoted dP´ below.

The air flow "V", i.e. the volume of air flowing through the gap, is: V = f (dP´, t)

where dP´ = differential pressure across the gap,
t = t(x) the grade of opening of the gap, which is function of distance x, and
t may represent a one-dimensional distance or a two-dimensional area.

Fig. 9 illustrates an example of how the apparatus may be designed in practice in the case when the partition is movable against a counteracting force. In this example, the partition 900 is thus movable when the pressure P_x inside the partition is changed. A fixedly attached valve member 902 extends through an orifice in the partition 900 so that a variable air gap 904 is created. The counteracting force is created by a spring 906. The partition 900 comprises a circumferential flexible membrane 900a attached to the enclosure, and a movement limiting member 900b which can move within a range limited by two end-stop members 908a and 908b attached to the enclosure. Thereby, the air gap 904 cannot be completely closed as determined by the end-stop member 908a.and cannot increase more than a certain maximum limit as determined by the end-stop member 908b.

Figs 10a, 10b and 10c illustrate three different positions of the partition 900 in Fig. 9 occurring at different pressures P_x inside the partition 900. Arrows indicate how the partition 900 is moved between the two end-stop members 908a and 908b where Fig. 10a illustrates an end position of the partition 900 that provides a minimum air gap and Fig. 10c illustrates an opposite end position of the partition 900 that provides a maximum air gap. The partition 900 can thus move between these two end positions depending on the varying pressure P_x inside the partition 900 so as to maintain a constant air flow through the air gap 904.

Further embodiments are possible to use in this solution, e.g. in any of the examples shown in Figs 3-6. In a possible embodiment, the orifice 302a, 402a, 502a, 602a in any of these examples may have a tapered inner surface so that the air gap 306, 406, 506, 606 is regulated when the movable partition or the valve member moves in response to variations of the pressure inside the partition is changed. This is illustrated in more detail by Fig. 11 where a fixedly attached valve member 1100a extends through an orifice 1102b in a movable partition 1102. The orifice 1102b has a tapered inner surface such that the air gap is variable depending on the displacement of the partition 1102 in response to variations of the pressure P_x inside the partition 1102. Such a tapered shape of the orifice may be applied in any of the above-described examples and embodiments, e.g. in the examples of Figs 3-6.

In another possible embodiment, the air conveying device 206, 308, 408, 508, 608 may be arranged to create an airflow for cooling or heating electronic equipment housed in the enclosure, e.g. as shown in Fig. 2. In yet another possible embodiment, the air conveying device may have a variable operating capacity for controlling the airflow, thereby causing said variations of the pressure inside the partition. This has also been mentioned above in several examples.

In further possible embodiments, a cabinet is provided which comprises a battery, an electronic equipment, and the apparatus according to any of the above-described embodiments, wherein the air conveying device is arranged to create an airflow for cooling or heating the electronic equipment.

Advantages that may be achieved by implementing any of the above-described embodiments include that insufficient or excessive ventilation of an enclosure holding a battery can be avoided or at least reduced, and still obtain satisfactory cooling or heating of any electronic equipment housed by the enclosure. The self-regulating valve function of this solution is wholly automatic and requires a minimum of maintenance. Further, the need for employing air filters to protect the electronic equipment and/or the battery from contaminated air can be reduced or even eliminated. It should also be noted that the apparatus described herein may be used solely for ventilating hydrogen gas emitted from the battery, that is with or without any electronic equipment present in the enclosure.

While the solution has been described with reference to specific exemplifying embodiments, the description is generally only intended to illustrate the inventive concept and should not be taken as limiting the scope of the solution. For example, the terms “enclosure”, “partition”, “valve member”, “air conveying device” and “electronic equipment” have been used throughout this disclosure, although any other corresponding entities, functions, and/or elements could also be used having the features and characteristics described here. The solution is defined by the appended claims.

CLAIMS

1. An apparatus for ventilation of an enclosure (300, 400, 500, 600) in which a battery (202) is housed, the apparatus comprising:

- a partition (302, 402, 502, 602) separating the enclosure from ambient air and comprising an orifice (302a, 402a, 502a, 602a),

- a valve member (304, 404, 504, 604) extending through the orifice to form a variable air gap (306, 406, 506, 606) for ventilation of the enclosure, and

- an air conveying device (308, 408, 508, 608) arranged to create a pressure (P_1, P_2) inside the partition which is different than a pressure (P_0) outside the partition such that air flows through the air gap,

wherein one of the partition and the valve member is movable against a counteracting force so as to regulate the air gap in response to variations of the pressure inside the partition such that a substantially uniform air flow is maintained through the air gap.

2. An apparatus according to claim 1, wherein the valve member (304, 504) is fixedly attached to the enclosure and the partition (302, 502) is flexibly attached to the enclosure so as to be movable relative the valve member when the pressure inside the partition is changed.

3. An apparatus according to claim 2, wherein the partition comprises a circumferential flexible membrane attached to the enclosure.

4. An apparatus according to claim 2 or 3, wherein at least one spring (310, 510) is arranged between the partition and the enclosure so as to create the counteracting force.

5. An apparatus according to claim 2 or 3, wherein the counteracting force is created by the weight of the movable partition.

6. An apparatus according to claim 1, wherein the partition (402, 602) is fixedly attached to the enclosure and the valve member (404, 604) is flexibly attached to the enclosure so as to be movable relative the partition when the pressure inside the partition is changed.

7. An apparatus according to claim 6, wherein at least one spring (410, 610) is arranged between the valve member and the enclosure so as to create said counteracting force.

8. An apparatus according to claim 6, wherein the counteracting force is created by the weight of the movable valve member.

9. An apparatus according to any of claims 1-8, wherein the apparatus is configured to be installed in an air inlet (312, 412) of the enclosure (300, 400).

10. An apparatus according to any of claims 2-5, wherein the apparatus is configured to be installed in an air inlet (312, 412) of the enclosure (300, 400) and the valve member (304) comprises a tapered element having a narrow section arranged substantially outside the partition and a wide section arranged substantially inside the partition.

11. An apparatus according to any of claims 6-8, wherein the apparatus is configured to be installed in an air inlet (312, 412) of the enclosure (300, 400) and the valve member (404) comprises a tapered element having a narrow section arranged substantially inside the partition and a wide section arranged substantially outside the partition.

12. An apparatus according to any of claims 1-8, wherein the apparatus is configured to be installed in an air outlet (512, 612) of the enclosure (500, 600).

13. An apparatus according to any of claims 2-5, wherein the apparatus is configured to be installed in an air outlet (512, 612) of the enclosure (500, 600) and the valve member (504) comprises a tapered element having a narrow section arranged substantially inside the partition and a wide section arranged substantially outside the partition.

14. An apparatus according to any of claims 6-8, wherein the apparatus is configured to be installed in an air outlet (512, 612) of the enclosure (500, 600) and the valve member (604) comprises a tapered element having a narrow section arranged substantially outside the partition and a wide section arranged substantially inside the partition.

15. An apparatus according to any of claims 1-14, wherein the orifice has a tapered inner surface so that the air gap is regulated when the movable partition or the valve member moves in response to variations of the pressure inside the partition.

16. An apparatus according to any of claims 1-15, wherein the air conveying device is arranged to create an airflow for cooling or heating electronic equipment (204) housed in the enclosure.

17. An apparatus according to claim 16, wherein the air conveying device has a variable operating capacity for controlling the airflow, thereby causing said variations of the pressure inside the partition.

18. A cabinet (200) comprising:

- a battery (202),

- an electronic equipment (204), and

- the apparatus according to any of claims 1-17 wherein the air conveying device (206) is arranged to create an airflow for cooling or heating the electronic equipment.

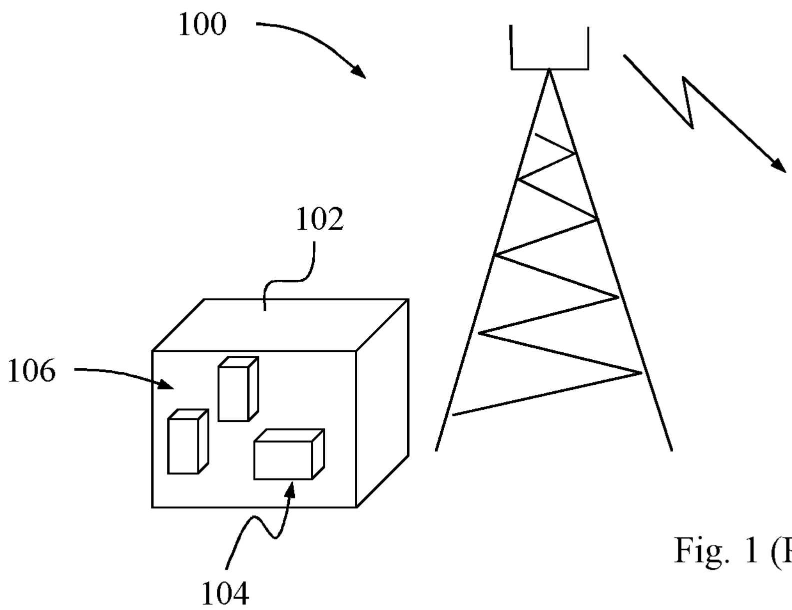

Fig. 1 (Prior art)

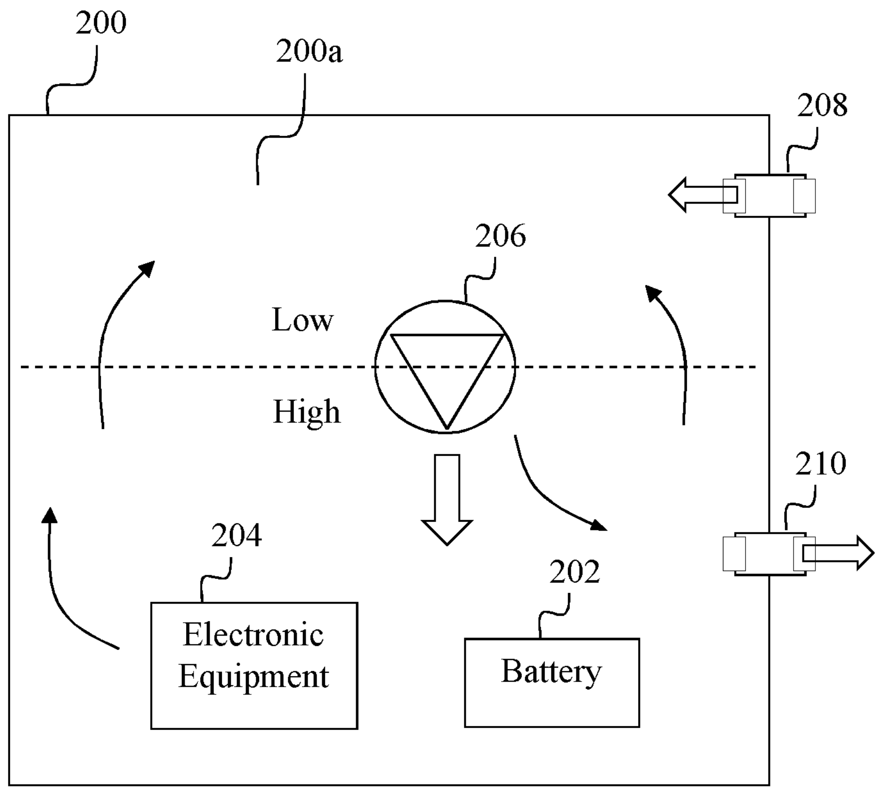

Fig. 2

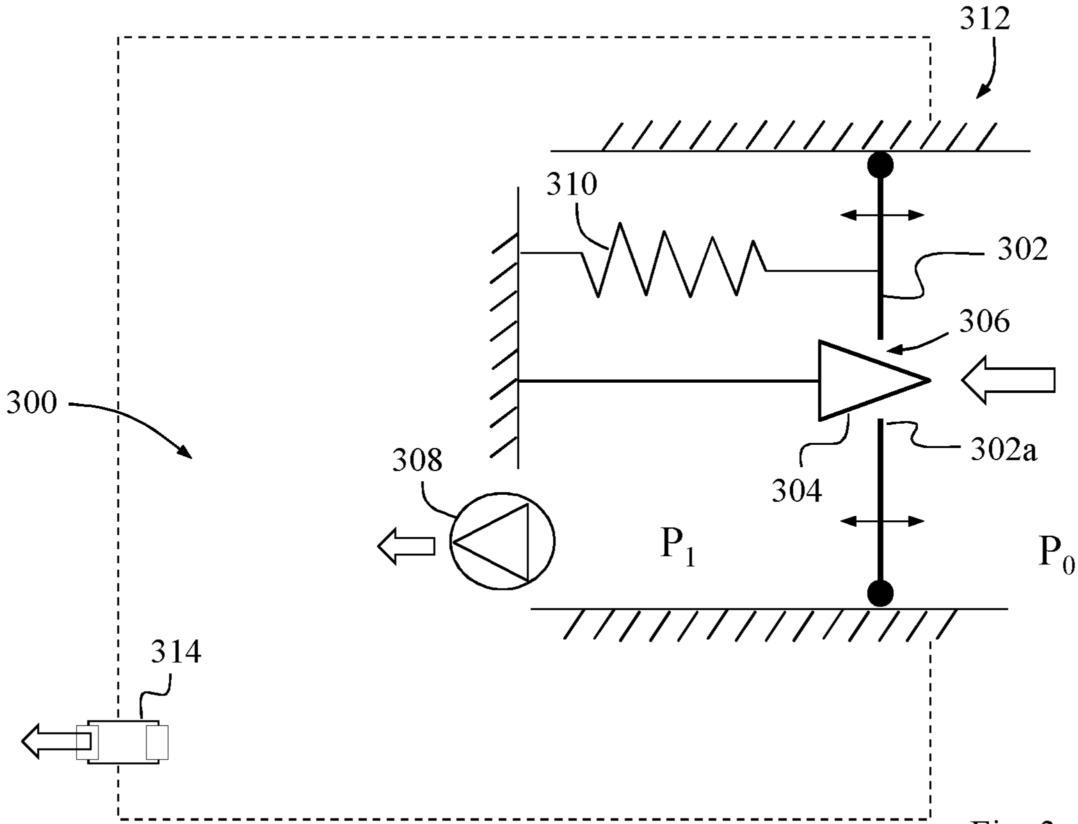
312
310
302
306
300
304
302a
308
P_1
P_0
314

Fig. 3

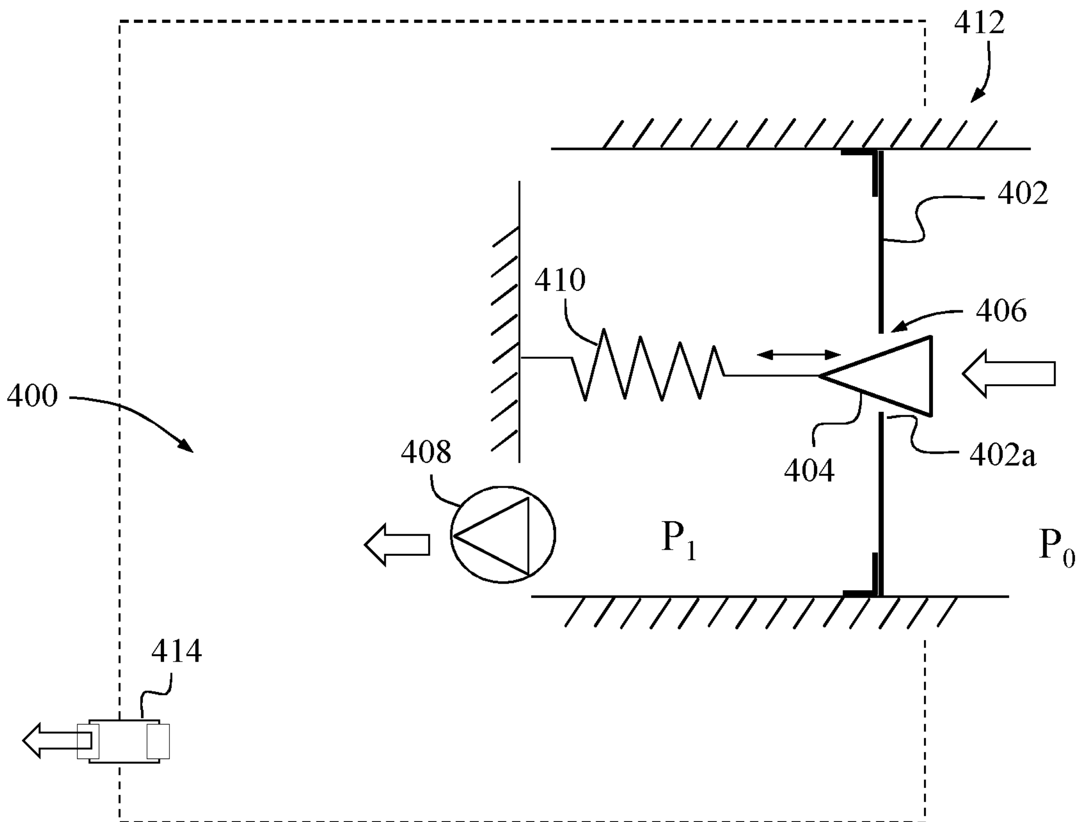
412
402
410
406
400
404
402a
408
P_1
P_0
414

Fig. 4

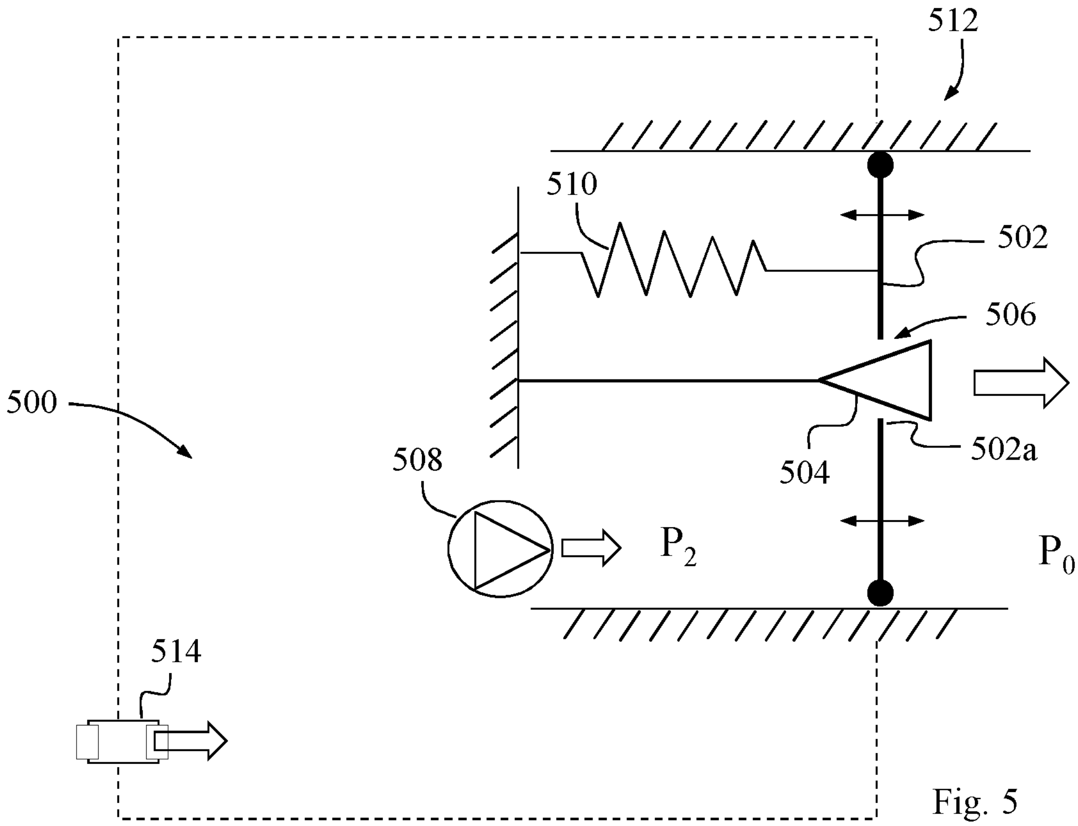
512
510
502
506
500
504
502a
508
P2
P0
514

Fig. 5

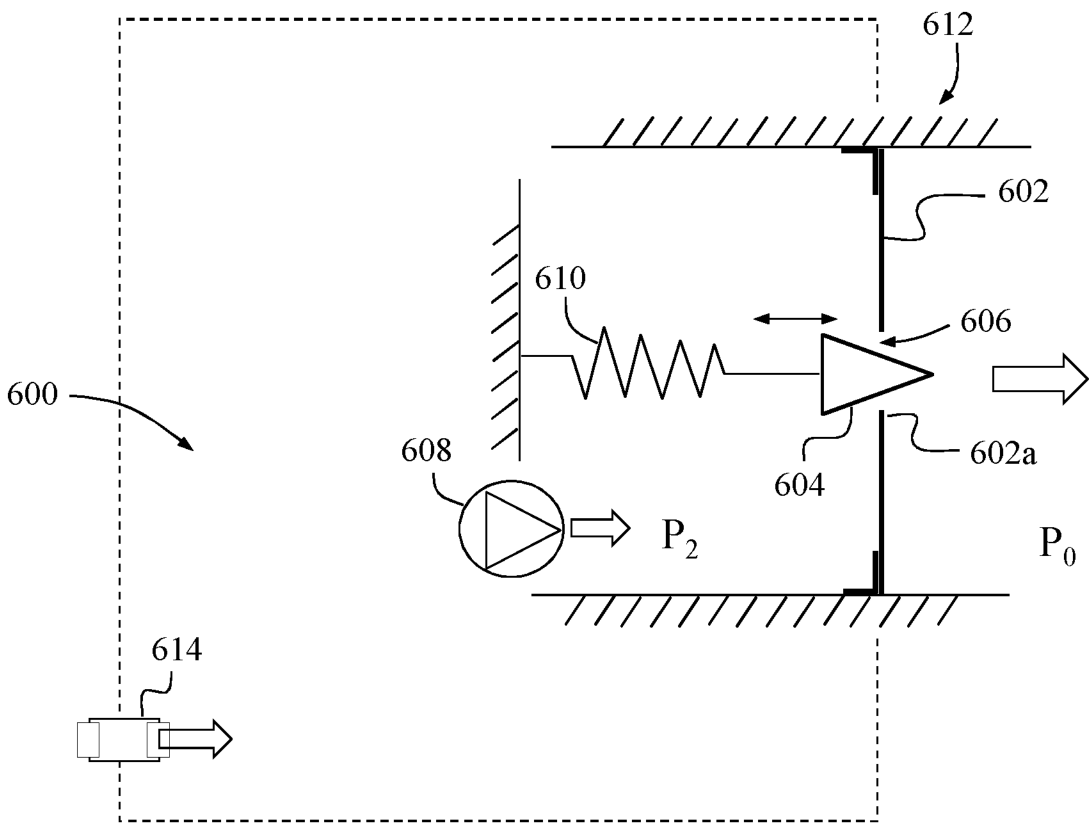
612
602
610
606
600
604
602a
608
P2
P0
614

Fig. 6

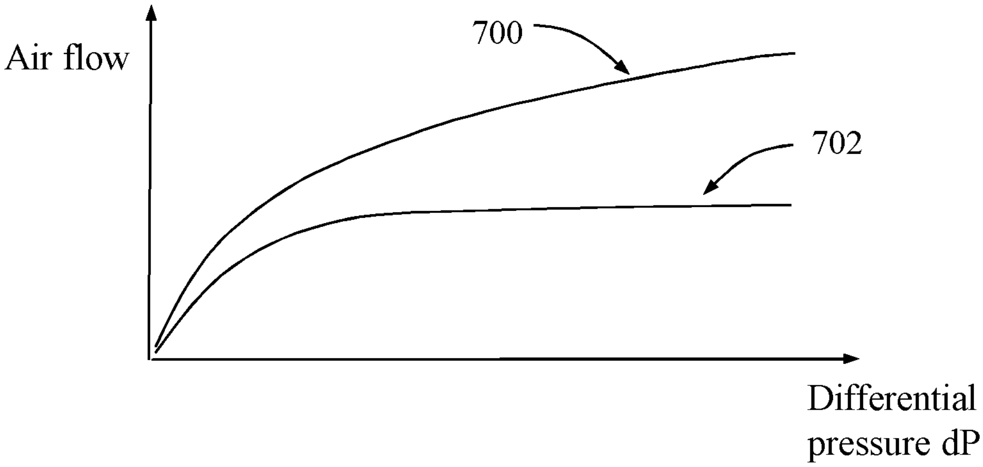

Fig. 7

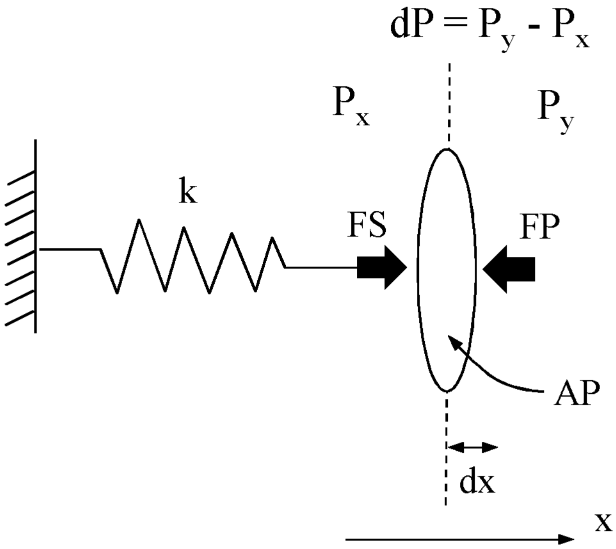

Fig. 8

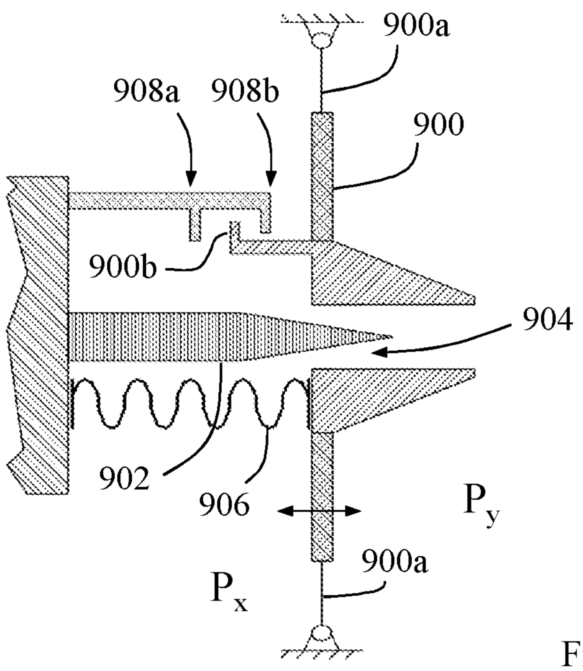

Fig. 9

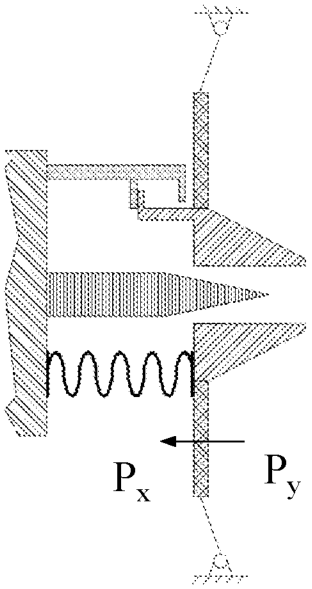

Fig. 10a

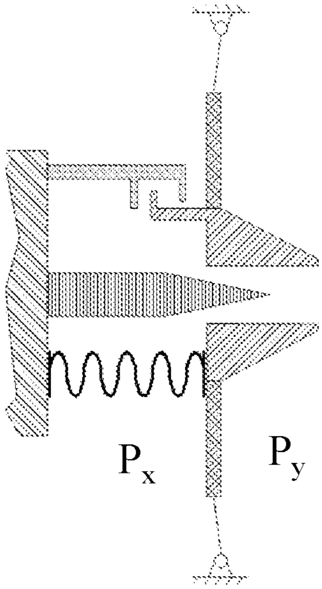

Fig. 10b

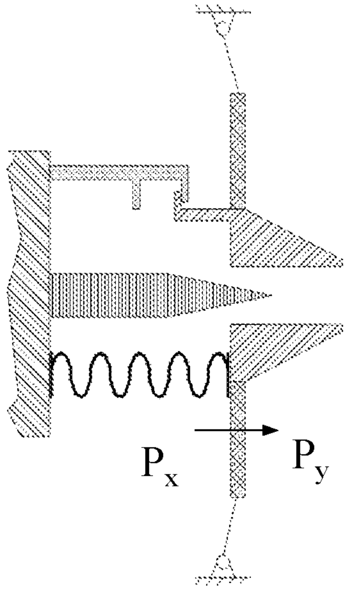

Fig. 10c

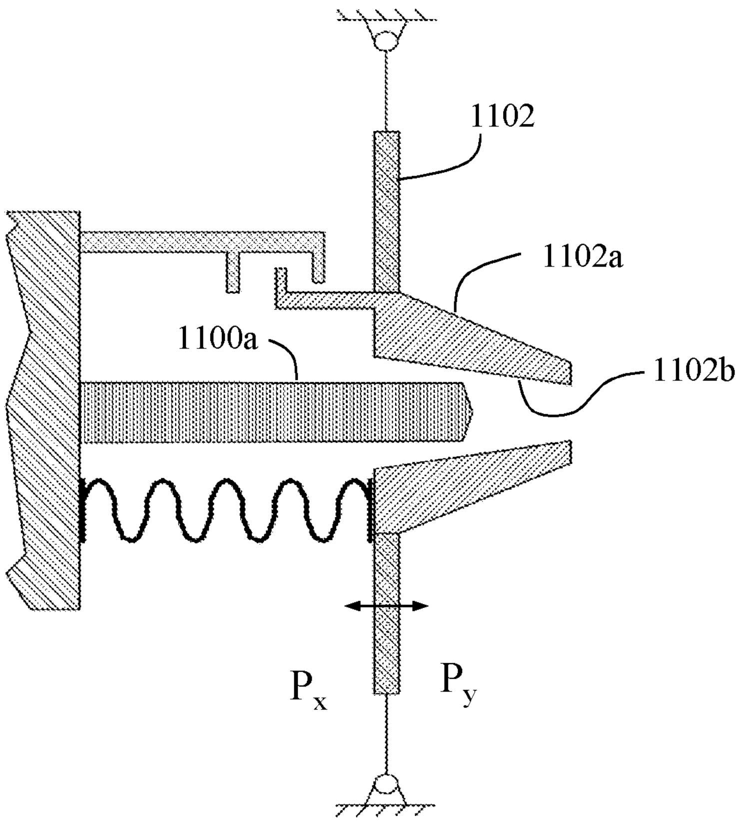

Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2014/051003

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M2/10 H01M2/02 H01M6/50
ADD.

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)
H01M F24F

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 practicable, 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 Y	EP 1 522 799 A2 (LTG AG [DE]) 13 April 2005 (2005-04-13) see, in particular, figures 1-18 and claims 1-12 -----	1,6,8-17 1-18
X Y	US 3 911 693 A (SEIGLER JACK D ET AL) 14 October 1975 (1975-10-14) see, in particular figure 3, items 48, 22 and 20; see claims 1-45 -----	1,6,8-17 1-18
X Y	US 2013/255309 A1 (WU GUOLIAN [US] ET AL) 3 October 2013 (2013-10-03) see, in particular figures 1-3 items 134, 130, 132 and items above wall 6 and right of wall 2. -----	1,6,8-17 1-18

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[X] Further documents are listed in the continuation of Box C.

[X] 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
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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
"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

Date of the actual completion of the international search	Date of mailing of the international search report
20 February 2015	02/03/2015

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, Fax: (+31-70) 340-3016	Rumbo, Angel

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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