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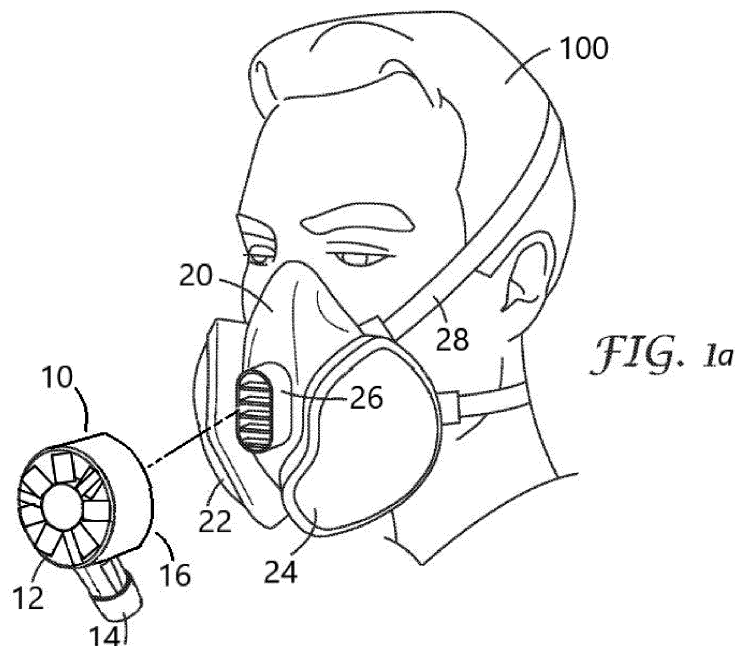
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(54) **POWERED EXHAUST APPARATUS FOR A PERSONAL PROTECTION RESPIRATORY DEVICE**

(57) The present disclosure relates to an exhaust apparatus 10, 10' for releasable connection to a personal protection respiratory device 20 that defines a filtered air volume adjacent to the face of a wearer 100 and comprises at least one exhalation valve 26, wherein the exhaust apparatus 10, 10' is configured to be in fluid connection with the at least one exhalation valve when the exhaust apparatus 10, 10' is connected to the personal protection respiratory device 20, and the apparatus comprises an fan 12, 12' configured to draw a portion of the wearer's 100 exhaled breath through the at least one

exhalation valve 26 at a high volumetric flow rate with low pressure when the exhaust apparatus 10, 10' is connected to the personal protection respiratory device 20. Using such an exhaust apparatus for releasable connection to a personal protection respiratory device improves the service lifetime of the personal protection respiratory device by reducing the amount of excess air drawn through the filter system of the respirator during the wearer's exhalation process. The present disclosure further relates to a respirator 70 comprising such an exhaust apparatus 10, 10'.



Description

TECHNICAL FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to an exhaust apparatus for personal protection respiratory devices, particularly negative pressure respirators. In particular, the present disclosure relates to an exhaust apparatus which can be releasably connected to a personal protection respiratory device. In use, the powered exhaust apparatus removes the hot and/or moist air that can often buildup inside a negative pressure respirator to significantly improve and enhance wearer comfort. The present disclosure further relates to a respirator with such an exhaust apparatus.

BACKGROUND

[0002] Negative pressure respirators are well known in the art. With respirators of this type, filtered air is drawn into the enclosed space between the inside of the respirator and a wearer's face through a filter system by the wearer's breathing action. When the wearer draws a breath, negative pressure is created in the respirator and air is drawn in through the filter system. When the wearer exhales a breath, spent air leaves the respirator through an exhalation valve and/or back through the filter system.

[0003] Although negative pressure respirators are available in many different configurations, and offer many different benefits, they may have one major drawback, that of the uncomfortable build-up of heat and/or moisture that can sometimes occur inside the respirator. The heat and/or moisture build-up is caused by the trapping of the wearer's exhaled breath in the cavity created between the respirator and the wearer's face. As the wearer works harder, and/or wears the respirator for extended periods of time, heat and/or moisture build-up may increase.

[0004] Many different solutions have been proposed in the prior art to eliminate, or at least minimise, the problem of heat and/or moisture build-up inside negative pressure respirators. For example, the addition of an exhaust apparatus comprising a radial or centrifugal fan to draw breathed air out of the negative pressure apparatus. These have as a side effect that excess air is drawn through the filter system during the inhalation and exhalation of the wearer, decreasing the service lifetime of the filters employed.

[0005] Accordingly it is therefore desirable to be able to find a way to maximise the filter service lifetime of negative pressure respirators while ensuring that negative pressure respirators can be worn comfortably for an extended period of time, regardless of the ambient temperature or weather conditions, and the type and intensity of the work being undertaken.

SUMMARY OF THE DISCLOSURE

[0006] The present disclosure aims to address these

issues by providing an exhaust apparatus for releasable connection to a personal protection respiratory device that defines a filtered air volume adjacent to the face of a wearer and comprises at least one exhalation valve, wherein the exhaust apparatus is configured to be in fluid connection with the at least one exhalation valve when the exhaust apparatus is connected to the personal protection respiratory device, and the apparatus comprises a powered fan configured to draw a portion of the wearer's exhaled breath through the at least one exhalation valve at a high volumetric flow rate with low pressure when the exhaust apparatus is connected to the personal protection respiratory device.

[0007] A high volumetric flow rate in the context of the present disclosure is meant to be a flow rate which is sufficient to move the used air out of the respiratory device during an exhalation cycle. In other words, the air exhaled by the user of the exhaust apparatus containing a higher CO₂ and moisture level is being moved out sufficiently fast. Typically, the flow rate is higher than the peak flow rate of the user of such exhaust apparatus, which is calculated as volume of air in each breath multiplied by number of breathes per minute multiplied by Pi (3,14). A high volumetric flow rate ensures that no used air is being re-breathed with the next inhalation cycle.

[0008] An advantage of using such a powered fan is that the lifetime of the exhaust apparatus can be prolonged compared to exhaust apparatuses comprising a high volumetric flow rate, high pressure fan assemblies, e.g. centrifugal fan assemblies. Advantageously, the use of a high volumetric flow rate, low pressure fan prolongs the service life of the filters of the personal protection respiratory device to which the exhaust apparatus is connected. High pressure fans like those incorporated into centrifugal fan assemblies tend to draw in excessive air through the filters of the personal protection respiratory device during the exhalation of the wearer. In normal use without the exhaust apparatus according to the present disclosure, air is only drawn in through the filters during the inhalation process of the wearer. A fan assembly with high volumetric flow rate at high pressure can therefore lead to excess air being drawn through the filters which is wasted as it is drawn in during exhalation and immediately drawn out of the filtered air volume through the exhalation valve without being breathed in by the wearer. This excess air that is filtered shortens the service life of the filters. Using a high volumetric flow rate, low pressure fan prevents such excess air drawn through the filters during exhalation, as the pressure generated by the high volumetric flow rate, low pressure fan is not sufficient to draw in additional air, thus increasing the service life of the filters. Furthermore, a fan with a high volumetric flow rate at high pressure having sufficient pressure to open the exhalation valve of the respiratory device during the inhalation of the wearer, can cause excess air to be drawn through the filters during inhalation which is additional wasted air. A further advantage of using a high volumetric flow rate, low pressure fan is that the comfort of the wear-

er during inhalation can be improved. At the beginning of the inhalation process there is a period of time when the exhalation valve has not yet closed again after the preceding exhalation process. During that time period the fan of the exhaust apparatus can counteract the inhalation action of the user. As the inhalation of the user is already hampered by the additional resistance provided by the filters, this excess impediment to unobstructed breathing can be both uncomfortable and exhausting to the wearer, especially over prolonged periods of wearing the personal protection respiratory device. A high volumetric flow rate at low pressure fan provides greatly reduced resistance to the wearer's inhalation when compared to centrifugal fan assemblies, thereby increasing the wearer's comfort.

[0009] In one embodiment, the powered fan is an axial fan. Centrifugal fan assemblies have a higher weight than axial fan assemblies of comparable size. Furthermore, in axial fan assemblies the flow direction of the propelled air stream is aligned with the rotation axis of the fan assembly while in centrifugal fan assemblies the air stream flows in a direction perpendicular to the axis of rotation of the fan assembly. Higher weight and force applied to the axis of rotation of a centrifugal fan assembly causes a higher gyroscopic resistance which causes a force counteracting the driving of the fan assembly by its motor. Advantageously, the use of an axial fan assemblies allows therefore to use motors which are not required to withstand as much wear and tear and are therefore cheaper to produce and incorporate, as well as last longer than motors used in centrifugal fan assemblies.

[0010] In one embodiment, the fan of the exhaust apparatus according to the present disclosure comprises means for controlling the pressure such that a low pressure is achieved. Such a means for controlling the pressure is advantageous because it allows for the use of fans which have a high volumetric flow rate and a comparably high pressure, which would otherwise, i. e. without controlling the pressure, be unsuitable for an exhaust apparatus according to the present disclosure. Thus, a wider range of fan may be suitable for using with the exhaust apparatus according to the present disclosure.

[0011] In another embodiment, the low pressure is defined as a pressure below a pressure capable of opening the exhalation valve of the respiratory device during the inhalation of the user. Such a low pressure is advantageous because opening of the exhalation valve during the inhalation is avoided thereby which would otherwise result in moving excess air out and in dragging fresh air through the filter cartridges. On the other hand, such a low pressure avoids that too much air is moved out of the exhaust device during the exhalation, i. e. where the exhalation device is open, which would otherwise lead to fresh air being dragged through the filter inside the exhaust device during the exhalation. Typically, the pressure suitable for opening the exhalation valve of the respiratory device may be 150 Pa, so that the pressure of the fan needs to be lower, e. g. 140 Pa.

[0012] The exhaust apparatus may further comprise an attachment means for releasably connecting the powered fan to the at least one exhalation valve. Such an attachment means is advantageous because it provides an easy and reliable way to attach the fan to the exhalation valve. For example, the attachment means may be selected from a group consisting of interference fit, screw thread, snap fit engagement, bayonet, quick release mechanism, slider and groove engagement, locking pin, locking clip and mechanical hook and loop fastener. These attachment means are especially easy to connect and release allowing for advantageously easy handling by the wearer, in particular providing an attachment means without the need for extra parts (snap fit, interference fit, slider and groove engagement, locking pin), providing an easy and reliable attachment (quick release, bayonet) and/or a cheap and easy to use attachment (locking clip, mechanical hook and loop fastener). Furthermore, for all of these attachment means, the use of adhesive is avoided which may otherwise produce unwanted outgassing into the respirator. Alternatively, the powered fan and the exhalation valve may be formed integrally, i. e. having one housing such that no attachment means is necessary between fan and exhalation valve.

[0013] The personal protection respiratory device may be selected from a group consisting of disposable, reusable, half mask, full face, particulate, gas and vapor and tight-fitting hood respirators. Each of these personal protection respiratory devices provides its own unique advantages and is useful depending on the situation of the wearer, for example the disposable respirators are simple and cheap, reusable respirators avoid waste, half mask respirators are durable with replaceable filters, full face respirators can provide additional eye protection, particulate respirators are useful to remove air borne particulates, gas and vapour respirators protect against certain gaseous or vaporous air contents, and tight-fitting hood respirators provide for additional face and head protection.

[0014] The fan may further be configured to rotate with a rotation speed generating a volumetric flow rate of between 0 to 180 litres per minute. As the average flow rate of a wearer lies in this range, the fan generating a flow rate within this range advantageously improves the comfort of the wearer. Such a flow rate is important to help moving out the user air as exhaled by the user of the exhaust apparatus so that no used air is being re-breathed with the next inhalation cycle.

[0015] Further, the fan may be configured to rotate with a rotation speed able to reduce the temperature inside the personal protection respiratory device by at least about 1 °C to 3 °C. This way, the exhaust apparatus can advantageously bring the temperature inside the personal protection respiratory device into a range comfortable for the wearer.

[0016] The fan may further be configured to rotate with a rotation speed able to reduce the rebreathed carbon

dioxide level inside the personal protection respiratory device by up to about 0.7 %. This way, the exhaust apparatus can advantageously bring the carbon dioxide level inside the personal protection respiratory device into a range comfortable for the wearer.

[0017] The exhaust apparatus may further comprise a power supply for the fan, the power supply being integrally mounted with the fan. This allows for an especially compact configuration of the exhaust apparatus, leading to an advantageously easy handling by the wearer.

[0018] Further, the exhaust apparatus may further include a power supply for the fan, the power supply being remotely positionable on the wearer. This allows for an advantageously comfortable distribution of weight on the wearer's body.

[0019] The fan of the exhaust apparatus may be directly connected to the exhalation valve of the exhaust apparatus, e. g. by means of screw fit, snap fit, form fit etc. Alternatively, the fan may be arranged remotely from the exhalation valve and be in fluid connection with the at least one exhalation valve via a breathing hose, tube, pipe, duct or channel. These means allow for advantageously reliable connection between the exhalation valve and the fan.

[0020] The present disclosure also provides a respirator comprising a mask body that comprises a filtering system, the mask body being dimensioned to define a filtered air volume adjacent to the face of a wearer, the mask body further comprises at least one exhalation valve for allowing exhalation of the wearer's exhaled breath, and an exhaust apparatus according to the present disclosure. An advantage of using such a respiratory device is that the lifetime of the exhaust apparatus can be prolonged compared to exhaust apparatuses comprising a high volumetric flow rate, high pressure fan assemblies, e. g. centrifugal fan assemblies.

[0021] Advantageously, the use of a high volumetric flow rate, low pressure fan prolongs the service life of the filters of the personal protection respiratory device to which the exhaust apparatus is connected. High pressure fans like those incorporated into centrifugal fan assemblies tend to draw in excessive air through the filters of the personal protection respiratory device during the exhalation of the wearer. In normal use without the exhaust apparatus according to the present disclosure, air is only drawn in through the filters during the inhalation process of the wearer. A fan assembly with high volumetric flow rate at high pressure can therefore lead to excess air being drawn through the filters which is wasted as it is drawn in during exhalation and immediately drawn out of the filtered air volume through the exhalation valve without being breathed in by the wearer. This excess air that is filtered shortens the service life of the filters. Using a high volumetric flow rate, low pressure fan prevents such excess air drawn through the filters during exhalation, as the pressure generated by the high volumetric flow rate, low pressure fan is not sufficient to draw in additional air, thus increasing the service life of the filters.

Furthermore, a fan with a high volumetric flow rate at high pressure having sufficient pressure to open the exhalation valve of the respiratory device during the inhalation of the wearer, can cause excess air to be drawn through the filters during inhalation which is additional wasted air. A further advantage of using a high volumetric flow rate, low pressure fan is that the comfort of the wearer during inhalation can be improved. At the beginning of the inhalation process there is a period of time when the exhalation valve has not yet closed again after the preceding exhalation process. During that time period the fan of the exhaust apparatus can counteract the inhalation action of the user. As the inhalation of the user is already hampered by the additional resistance provided by the filters, this excess impediment to unobstructed breathing can be both uncomfortable and exhausting to the wearer, especially over prolonged periods of wearing the personal protection respiratory device. A high volumetric flow rate at low pressure fan provides greatly reduced resistance to the wearer's inhalation when compared to centrifugal fan assemblies, thereby increasing the wearer's comfort. The respirator may optionally further comprise an air distribution manifold in fluid connection with the filtering system. This advantageously improves the comfort of the wearer by evenly distributing the air inside the respirator.

[0022] According to one embodiment, the air distribution manifold is connected to inhalation ports. The manifold outlet is generally located above the wearer's eye line. An air flow through the respiratory device and the exhaust apparatus according to the present disclosure is created thereby, whereby the wearer creates a negative pressure through breathing which draws air in through the filter system and then downwards towards the nose and mouth of the wearer. When the wearer exhales a breath, spent air is drawn out of the one-way exhalation valve diaphragm in the respirator by the exhaust apparatus. By having such a directional air flow inside the mask, with the "cooler" ambient air being drawn towards the top of the respiratory mask and then downwards across both the visor of the respiratory mask and the wearer's face, this gives an enhanced cooling effect for the wearer and further improvements in terms of preventing visor misting.

[0023] According to another embodiment, the powered fan of the exhaust apparatus of the respirator is an axial fan. The advantage of such an axial fan is described above.

[0024] Where appropriate, the above-mentioned configurations and developments can be combined in any manner. Further possible configurations, developments and implementations of the disclosure also include combinations, which are not explicitly mentioned, of features of the disclosure which have been described previously or are described in the following with reference to the embodiments. In particular, in this case, a person skilled in the art will also add individual aspects as improvements or supplements to the basic form of the present disclosure.

sure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] The present disclosure will now be described by way of example only, and with reference to the accompanying drawings, in which:

Figure 1a is an exploded view of an exhaust apparatus 10 according to one embodiment of the present disclosure for releasable connection to a personal protection respiratory device 20;

Figure 1b is an exploded view of an exhaust apparatus 10 according to another embodiment of the present disclosure for releasable connection to a personal protection respiratory device 20;

Figure 2 shows a front side perspective view of the exhaust apparatus 10 of Figure 1a connected to the personal protection respiratory device 20;

Figure 3 is a cross-sectional side view of the exhaust apparatus 10 taken along the dashed line A'-A" in Figure 6;

Figure 4 illustrates a sectional side view of the exhaust apparatus 10 being operable to draw a portion of the wearer's 100 exhaled breath through an exhaust valve 26 on the personal protection respiratory device 20;

Figure 5 is a side view of the exhaust apparatus 10 of Figure 1 connected to the personal protection respiratory device 20;

Figure 6 shows a front view of the exhaust apparatus 10 of Figure 1 connected to the personal protection respiratory device 20;

Figure 7 illustrates a front side perspective view of the exhaust apparatus 10 according to the present disclosure, further showing a remotely positionable battery pack 46;

Figure 8 shows a front view of the exhaust apparatus 10 according to the present disclosure being connected to a full facepiece respiratory device 70;

Figure 9 is a sectional side view of the exhaust apparatus 10 according to the present disclosure connected to a full facepiece respiratory device 70; and

Figure 10 is a diagram showing the pressure inside a filtered air volume of a respirator plotted against various flow rates of air into or out of the filtered air volume.

[0026] The appended drawings are intended to provide further understanding of the embodiments of the present disclosure. They illustrate embodiments and, in conjunction with the description, help to explain principles and concepts of the present disclosure. Other embodiments and many of the advantages mentioned become apparent in view of the drawings. The elements in the drawings are not necessarily shown to scale.

[0027] In the drawings, like, functionally equivalent and identically operating elements, features and components are provided with like reference signs in each case, unless stated otherwise.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0028] The present disclosure has adopted the approach of using an exhaust apparatus for releasable or permanent connection to a personal protection respiratory device such that it improves the comfort and overall experience for the wearer. Use of the present disclosure allows the respirator to be worn for intensive work, and/or for long periods of time, and/or in hot and humid environmental conditions by removing the heat and/or moisture build-up inside the respirator. The benefit felt by the wearer occurs both at very low work rates, e. g. whilst performing sedentary tasks, but the effect can also be increased as work rate increases. The use of a powered exhaust apparatus which draws the hot air and moisture out of the enclosed space between the inside of the respirator and the wearer, means that the difficulties sometimes experienced in hot and humid conditions or after extended periods of use are minimized or removed completely. Advantageously, the act of drawing the hot and moist air out of the respirator also makes breathing easier for the wearer. This is because the first portion of the next breath of the wearer is fresh un-breathed air, rather than the last portion of the previously exhaled breath. This also gives improvements in terms of the carbon dioxide levels inside the respirator.

[0029] Figure 1a is an exploded view of an exhaust apparatus 10 according to the present disclosure which is able to releasably connect or engage with a personal protection respiratory device 20. Whilst the respirator 20 that is illustrated in Figures 1a, 2, 4, 5, 6, 8 and 9 is indicative of the 3M™ 4000 Series of gas, vapor and particulate respirators manufactured by 3M Company located in St. Paul, Minnesota, U. S. A., U. S. A., the exhaust apparatus 10 of the present disclosure can be utilized with any negative pressure respiratory device 20. The skilled person will appreciate that the term "respirator" or "respiratory mask", as used interchangeably herein, is intended to mean a breathing device worn to prevent the

inhalation of hazardous substances, particles, vapors or noxious gases. The term "negative pressure respiratory mask" is intended to cover any respirator in which the air pressure inside the mask becomes lower than the ambient air pressure when the wearer inhales.

[0030] A negative pressure respiratory mask 20 as described herein is used to mean any form of respirator intended to fit the face of the wearer 100 in a substantially sealed configuration causing the air inhaled and exhaled by the wearer 100 to pass through a filter body or a filter portion of the respirator. Negative pressure respiratory mask 20 can also be a full or half facepiece mask, depending upon the hazard of concern. Again, these masks utilize a filter which prevents the inhalation of contaminants, particles, gases and vapors from the air inhaled by the wearer. Some common examples of this type of respirator are manufactured by 3M Company located in St. Paul, Minnesota, U. S. A., U. S. A., and include the 3M™ 6000 and 7000 Series of reusable respirators or tight-fitting hood facepiece respirators.

[0031] Disposable respirators, such as the 3M™ 8000 and 9000 Series of cup-shaped and flat-folded products, are lightweight single-piece respirators that employ a filter media which removes particulates and mists from the air stream as the wearer draws a breath. The entire unit is designed to be discarded after some extended period or a single use or single shift, depending on the contaminant. Filtering facepieces, such as the 3M™ 6000 and 7000 Series are generally reusable products and which can have replaceable filter cartridges. Typically one or two cartridges attach securely to half mask or full facepiece which has built into it a corresponding number of valves for inhalation, and usually one for exhalation.

[0032] The personal protection respiratory device 20 that is illustrated in Figure 1a is a 3M™ 4251 Valved Filtering Half Face Respirator. As shown in Figure 1, a pair of filter cartridges 22, 24 are integrally attached to the respirator mask 20 at respective inhalation ports (not shown). Each of the inhalation ports includes a respective inhalation valve (not shown) on the inside of the respirator mask 20 which open as a wearer 100 draws a breath. The face mask 20 has an exhaust valve 26 with a one-way exhalation valve diaphragm (shown as reference numeral 36 in Figure 4) and adjustable straps 28 for attachment to the wearer 100.

[0033] The respiratory mask 20 has a conformable gasket or seal (not shown here, see Fig. 8) which generally encloses the wearer's 100 mouth and nose. Since a good seal is needed to ensure filtration of the contaminants one major drawback is that sometimes an uncomfortable build-up of heat and/or moisture is noticed by the wearer 100 inside the respirator 20. As the wearer 100 works harder, and or wears the respirator 20 for extended periods of time, heat and/or moisture build-up can occur. The heat and/or moisture build-up is caused by the trapping of the exhaled breath in the cavity created between the respirator 20 and the wearer's 100 face.

[0034] Figure 1b is an exploded view of an exhaust

apparatus 10' according to another embodiment of the present disclosure. The exhaust apparatus 10' is similar to the exhaust apparatus 10 as shown in Fig. 1a except that the fan 12' is not an axial fan. The fan 12' may, for example, be a centrifugal fan 12' or the like. Fig. 1b further shows a means 11 for controlling the pressure of the fan 12' such that a high volumetric flow rate at low pressure is achieved. The means 11 is in fluid connection to the fan 12' on the one hand and to the exhalation valve 26 on the other hand.

[0035] As further illustrated in Figures 1a and 2, the present disclosure incorporates an exhaust apparatus 10 having a generally elongate form. The exhaust apparatus 10 includes an axial fan 12 which is contained inside a housing 16. The axial fan 12 is shown in more detail in Figure 3. To control the operation of the axial fan 12, a switch mechanism 14 is accessible to the wearer 100. The switch mechanism 14 can have a simple on/off mode of operation or can include a variable adjustment so that the wearer 100 can optimize the desired speed of the axial fan, and hence, cooling effect based upon the environmental conditions, the task the wearer 100 is undertaking, and the wearer's personal choice.

[0036] A cooling effect is achieved by the use of such an exhaust apparatus 10 as described further herein. When a wearer 100 inhales a breath, "cooler" ambient air is drawn into the respiratory mask 20 either through the filter cartridges 22, 24 as shown in Figures 1 and 2 for a reusable mask, or through, for example, a filter portion or filtering mask body of the respirator, as with a disposable mask. Heat and/or moisture build-up is then caused by trapping the exhaled breath in the cavity created between the respirator 20 and the wearer's 100 face. When operated, the exhaust apparatus 10 of the present disclosure draws this warm and moist air out through the exhaust valve 26 and reduces the exhalation breathing resistance, as described below. This produces a noticeable cooling benefit for the wearer 100.

[0037] The exhaust apparatus 10 solves this problem because it draws the hot air and moisture out of the enclosed space between the inside of the respirator 20 and the wearer 100. The act of drawing the hot and humid air out of the respirator 20 also makes breathing easier for the wearer 100. This is because the first portion of the next breath of the wearer 100 is fresh un-breathed air, rather than the last portion of the previously-exhaled breath. This also gives improvements in terms of carbon dioxide reduction inside the mask 20.

[0038] As the exhaust apparatus 10 comprises an axial fan 12, advantageously a high volumetric flow rate, low pressure axial fan, less excess air is drawn through the filter cartridges 22, 24 during the exhalation of the wearer 100, when compared to exhaust apparatuses comprising radial fans. This prolongs the service life of the filter cartridges 22, 24 of the respirator 20 to which the exhaust apparatus 10 is connected.

[0039] The skilled person will appreciate that since the exhaust apparatus 10 is fluidally connected to the ex-

haust valve 26 on the respiratory mask 20 any over-breathing of the axial fan 12 (i. e., back flow through the axial fan 12 caused by inhalation by the wearer 100) is prevented by the one-way exhaust valve 26 on the respiratory mask 20. Positioning the exhaust apparatus 10 on the one-way exhaust valve 26 ensures that no contaminants, particulates, mists, vapors or gases are inhaled by the wearer 100 and the integrity of the personal protection respiratory device 20 is maintained. The exhaust apparatus 10 is designed to create just enough airflow and pressure to generate the cooling effect, which enables the unit to be made small and light enough to be attached to even a disposable fabric respirator, in fact any respirator that includes an exhaust valve 26.

[0040] Figure 3 shows further detail on the operation of the exhaust apparatus 10 according to the present disclosure and such is a cross-sectional side view of the exhaust apparatus 10 taken along the dashed line A'-A" in Figure 6. The housing 16 of the exhaust apparatus 10 is shaped to releasably connect by way of an interference fit to the shape and dimensions of the respective exhaust valve 26 situated on the respiratory mask 20. Whilst the exhaust apparatus 10 described herein in relation to Figure 3 connects by way of an interference fit, the skilled person will appreciate that any form of releasable connection to the exhaust valve 26 is possible, including, for example, connection by way of a screw thread, snap fit engagement, bayonet, quick release mechanism etc. The above list is in no way intended to be limiting and exhaustive.

[0041] The exhaust apparatus 10 includes an axial fan 12 which comprises a motor 30 and rotor blades 32. The output of the axial fan vents through a series of openings on the apparatus 10. The axial fan is contained inside the housing 16, and is configured to draw air through the exhaust apparatus 10. The air flow through the apparatus 10 is shown illustratively via the dashed lines A in Figure 3.

[0042] The exhaust apparatus 10 includes at least one power source, which is typically at least one battery 34. The battery 34 can be any commercially available battery 34, although the skilled person will appreciate that a compromise may be needed in terms of size and weight of the battery 34, and the capacity and duration of the battery 34. To control the operation of the axial fan 12, a switch mechanism 14 is accessible to the wearer 100. The switch mechanism can have a simple on/off mode of operation or can include a variable adjustment so that the wearer 100 can optimize the desired cooling effect based upon the environmental conditions, the task the wearer 100 is undertaking and personal choice.

[0043] The axial fan 12 comprises rotor blades 32, which are affixed to a toroidal magnet 37. The magnet 37 is arranged to rotate around a stator 30 of an electric motor 30 which is affixed to a shaft 38 and can be controlled by a printed circuit board 39.

[0044] The operation of the exhaust apparatus 10 is further illustrated in Figure 4 which shows a sectional

side view of the exhaust apparatus 10 being operable to draw a portion of the wearer's 100 exhaled breath through a exhaust valve 26 on the personal protection respiratory device 20. The illustrative air flow through the respiratory mask 20 and exhaust apparatus 10 being denoted by arrows A. For sedentary tasks, a noticeable cooling effect is experienced by the wearer 100 when the axial fan 12 is configured to operate at a volumetric flow rate of between 0 to 50 litres per minute through the exhaust valve 26. For arduous work, the axial fan 12 may be configured to operate at a volumetric flow rate of over 180 litres per minute through the exhaust valve 26.

[0045] Further illustrations of the exhaust apparatus 10 according to the present disclosure are shown in Figures 5 and 6. These show just how a purpose-designed apparatus 20 can be produced which is small, lightweight and balanced on the mask 20. Different designs of apparatus 10 are envisaged and different purpose-designed exhaust apparatuses 10 could also be styled to complement their respective negative pressure respirators 20, which all work in accordance with the mode of operation described herein.

[0046] Figure 7 shows a front side perspective view of an exhaust apparatus 10 according to the present disclosure, and further showing a remotely positionable battery pack 46. Figure 8 shows that the apparatus 10 can be configured with a breast pocket-mounted battery pack 46 that incorporates controls, such as an on/off switch 52 and speed adjuster 54, and display 56. By being breast pocket-mounted, and which attach to a wearer's clothing via clip 48, the controls are located in an easy to operate position and the visual display 56 showing battery life is located within the field of view of the wearer 100. The breast pocket-mounted battery pack 46 is connected to the axial fan 12 in exhaust apparatus 10 via a wired connection 50.

[0047] On many respiratory masks 20, especially disposable respirators, it may be desirable to have a separate battery pack 46 to reduce the weight and/or the size of the exhaust apparatus 10. By having a separate battery 46, larger capacity batteries can be used, leading to a longer operational time. A full range of display 56 options can then be located in the battery pack 46. These can include basic-colored LEDs, LED bargraphs or alphanumeric displays. More complex Graphical User Interface options, including visual and aural alarms/status indicators for flow range, mask pressure, battery, and remaining run time could also be used.

[0048] Whilst Figure 7 shows that the remote battery pack 46 is breast-mounted this is in no way intended to be limited as any number of remotely positionable battery configurations are envisaged, such as, for example, belt or waist mounted, helmet or headband mounted, arm or clip mounted.

[0049] Figures 8 and 9 illustrate how an exhaust apparatus 10 according to the present disclosure can be utilized with a full facepiece respiratory device 70. The respirator 70 that is illustrated in Figures 8 and 9 is indic-

ative of the 3M™ 6800 Full Facepiece Reusable Respirator manufactured by 3M Company located in St. Paul, Minnesota, U. S. A. As shown in Figures 8 and 9, filter cartridges 74 are attached at either side of the respirator mask 70 at respective inhalation ports 72.

[0050] Each of the inhalation ports 72 has a respective inhalation valve (not shown) located on the inside of the respirator mask 70 which open as a wearer 100 draws a breath. The face mask 70 includes an exhaust valve 80 with a one-way exhalation valve diaphragm 36, and adjustable straps (not shown) for attachment to the wearer 100.

[0051] The respiratory mask 70 has a conformable gasket or seal (not shown here) which generally encloses the wearer's 100 face. Since a good seal is needed to ensure filtration of the containments one major drawback is that sometimes an uncomfortable build-up of heat and/or moisture is noticed by the wearer 100 inside the respirator 70. As the wearer 100 works harder, and or wears the respirator 70 for extended periods of time, heat and/or moisture build-up can occur. The heat and/or moisture build-up is caused by the trapping of the exhaled breath in the cavity created between the respirator 20 and the wearer's 100 face. In a full facepiece respirator 70 the build-up of trapped hot and moist air can also cause the additional problem of visor misting.

[0052] As described above, the exhaust apparatus 10 of the present disclosure is operable to draw a portion of the wearer's 100 exhaled breath through the one-way exhalation valve diaphragm 36 on the personal protection respiratory device 70 to significantly improve and enhance wearer comfort. Figures 8 and 9 also show how a standard full facepiece respiratory device 70 can be modified to more effectively control or direct the air flow inside the respirator 70 to give even better improvements in terms of visor misting and the cooling effect experienced by the wearer 100.

[0053] The respiratory device 70 shown in Figures 8 and 9 also includes an additional air distribution manifold 76 that is connected to each of the inhalation ports 72. Located generally above the wearer's 100 eye line is the manifold outlet 78. The air flow through the respiratory device 70 and exhaust apparatus 10 is shown illustratively via the bold lines A in Figures 8 and 9. As can be seen, as the wearer 100 draws a breath, negative pressure is created in the respirator 70 and air is drawn in through the filter system, comprising the inhalation ports 72, filter cartridges 74, air distribution manifold 76, and the air exits at inside the mask 70 at the manifold outlet 78. The air is then drawn downwards towards the nose and mouth of the wearer 100. When the wearer 100 exhales a breath, spent air is drawn out of the one-way exhalation valve diaphragm 36 in the respirator 70 by the exhaust apparatus 10. By having such a directional air-flow inside the mask 70, with the "cooler" ambient air being drawn towards the top of the respiratory mask 70 and then downwards across both the visor of the respiratory mask 70 and the wearer's 100 face, this gives an

enhanced cooling effect for the wearer 100 and further improvements in terms of preventing visor misting.

[0054] Figure 10 shows the pressure inside a filtered air volume adjacent to the face of the wearer of a respirator against the flow rate into or out of the filtered air volume adjacent to the face of the wearer. The pressure inside the filtered air volume adjacent to the face of the wearer is here shown as the difference between the pressure inside the filtered air volume and the outside pressure, wherein positive pressure indicates that the pressure inside the filtered air volume is higher than the outside pressure and negative pressure indicates that the pressure inside the filtered air volume is lower than the outside pressure.

[0055] Line 110 in Figure 10 shows how the pressure inside a respirator changes with exhalation flow rate when no fan is fitted to the respirator exhalation port. The wearer's exhalation causes a positive pressure to build inside the filtered air volume adjacent to the face of the wearer which works against the resistance of the exhalation valve to push air through the exhalation valve out of the filtered air volume adjacent to the face of the wearer. The pressure and the exhalation flow rate are approximately directly proportional to each other. A human breathing cycle is approximately sinusoidal. A typical exhalation flow rate is between 30 l/min and 95 l/min. A typical peak exhale flow rate is about 160 l/min, however this does vary with work rate.

[0056] For reference, line 112 in Figure 10 shows how the pressure inside the respirator changes with inhalation flow rate when no fan is fitted to the respirator. The wearer is breathing against the resistance of the filters and inhalation valve and therefore causing a negative pressure inside the respirator, which causes air to be drawn through the filters into the filtered air volume adjacent to the face of the wearer. The negative pressure and inhalation flow rate are approximately directly proportional to each other, wherein the graph showing the pressure against the inhalation flow rate has a steeper slope than the graph showing the pressure against the exhalation flow rate, due to the filters having a much greater pressure drop than the exhalation valve.

[0057] Line 114 in Figure 10 shows the pressure inside the filtered air volume when a typical radial or centrifugal fan is drawing air out of the filtered air volume via the exhalation port at the flow rate shown. Up until an exhalation flow rate of about 150 l/min, the fan has the effect of lowering the pressure inside the mask during the exhalation cycle from the level it would have been with no fan. This is the effect enjoyed by the wearer, where the humid and CO₂ laden air is drawn out of the respirator. When the person is exhaling air at a flow rate less than the fan can produce, the pressure inside the respirator is negative. In this state, there is more air being drawing out of the filtered air volume by the radial fan is than exhaled by the wearer, and therefore an additional airflow is being drawn in through the filters. In Figure 10, this state is shown between exhalation flow rates from 0 to

approximately 75 l/min.

[0058] Line 116 in Figure 10 shows the pressure inside the filtered air volume when a typical axial fan is drawing air out of the respirator via the exhalation port at the flow rate shown. Up until an exhalation flow rate of about 140 l/min, the fan has the effect of lowering the pressure inside the mask during the exhalation cycle from the level it would have been with no fan. For the axial fan, the pressure drop from the curve for exhalation without any fan is lower when compared to the pressure drop for a radial fan. Consequently, the range where the pressure inside the filtered air volume is negative, and therefore excess air is drawn into the filtered air volume through the filters, is only between 0 and approximately 55 l/min. Consequently, the amount of excess air drawn in through the filters during exhalation is less than when a radial fan is used.

[0059] Therefore, an axial fan still has the effect of reducing the exhalation breathing resistance, but also reduces the detrimental effect on filter service life when compared to radial fans.

[0060] Although the present disclosure has been described in the above by way of preferred embodiments, it is not limited thereto, but rather can be modified in a wide range of ways. In particular, the disclosure can be changed or modified in various ways without deviating from the core of the disclosure. For example, although particular examples refer to implementing the present disclosure with respirators fitted with combined particulate and gas and vapor filters, this is in no way intended to be limiting as, in use, the present disclosure has been implemented and utilized with any negative pressure respiratory mask including, but not limited to disposable, reusable, half mask, full face, gas and vapour and tight-fitting hood respirators.

Claims

1. An exhaust apparatus (10, 10') for releasable connection to a personal protection respiratory device (20) that defines a filtered air volume adjacent to the face of a wearer (10, 10') and comprises at least one exhalation valve (26), wherein the exhaust apparatus (10, 10') is configured to be in fluid connection with the at least one exhalation valve when the exhaust apparatus (10, 10') is connected to the personal protection respiratory device (20), and the apparatus comprises a powered fan (12, 12') configured to draw a portion of the wearer's (10, 10') exhaled breath through the at least one exhalation valve (26) at a high volumetric flow rate with low pressure when the exhaust apparatus (10, 10') is connected to the personal protection respiratory device (20).
2. The exhaust apparatus (10, 10') according to claim 1, wherein the fan (12, 12') is an axial fan.
3. The exhaust apparatus (10, 10') according to any one of claims 1 or 2, wherein the fan (12, 12') comprises means (11) for controlling the pressure such that a low pressure is achieved.
4. The exhaust apparatus (10, 10') according to anyone of claims 1 to 3, wherein low pressure is defined as a pressure below a pressure capable of opening the exhalation valve (26) during inhalation of the user.
5. The exhaust apparatus (10, 10') according to any one of claims 1 to 4, wherein the low pressure is in the range of 0 Pa to 140 Pa.
6. The exhaust apparatus (10, 10') according to any one of claims 1 to 5, further comprising an attachment means for releasably connecting the fan (12, 12') to the at least one exhalation valve (26), wherein the attachment means optionally is selected from a group consisting of interference fit, screw thread, snap fit engagement, bayonet, quick release mechanism, slider and groove engagement, locking pin, locking clip and mechanical hook and loop fastener.
7. The exhaust apparatus (10, 10') according to any of the preceding claims, wherein the personal protection respiratory device (20) is selected from a group consisting of disposable, reusable, half mask, full face, particulate, gas and vapor and tight-fitting hood respirators.
8. The exhaust apparatus (10, 10') according to any of the preceding claims, wherein the fan (12, 12') is configured to rotate with a rotation speed generating a volumetric flow rate of between 0 to 180 litres per minute.
9. The exhaust apparatus (10, 10') according to any of the preceding claims, wherein the fan (12, 12') is configured to rotate with a rotation speed able to reduce the temperature inside the personal protection respiratory device (20) by at least about 1 °C to 3 °C.
10. The exhaust apparatus (10, 10') according to any of the preceding claims, wherein the fan (12, 12') is configured to rotate with a rotation speed able to reduce the rebreathed carbon dioxide level inside the personal protection respiratory device (20) by up to about 0.7 %.
11. The exhaust apparatus (10, 10') according to any of the preceding claims, further comprising a power supply (34) for the fan (12, 12'), the power supply (34) being integrally mounted with the housing of the fan (12, 12').

12. The exhaust apparatus (10, 10') according to any one of claims 1 to 10, further comprising a power supply (46) for the fan (12, 12'), the power supply (46) being positionable separately from the fan on the wearer (10, 10'). 5
13. The exhaust apparatus (10, 10') according to any of the preceding claims, wherein the fan (12, 12') is arranged remotely from the exhalation valve and wherein the fan is in fluid connection with at least one exhalation valve (26) via a breathing hose, tube, pipe, duct or channel. 10
14. Respirator (70), comprising: 15
- a mask body that comprises a filtering system, the mask body being dimensioned to define a filtered air volume adjacent to the face of a wearer (100), the mask body further comprises at least one exhalation valve (80) for allowing exhalation of the wearer's exhaled breath; and 20
- an exhaust apparatus (10, 10') according to any one of claims 1 to 13, wherein the respirator optionally comprises an air distribution manifold (76) in fluid connection with the filtering system. 25
15. The respirator (70) according to claim 14, wherein the powered fan (12, 12') is an axial fan (12, 12'). 30

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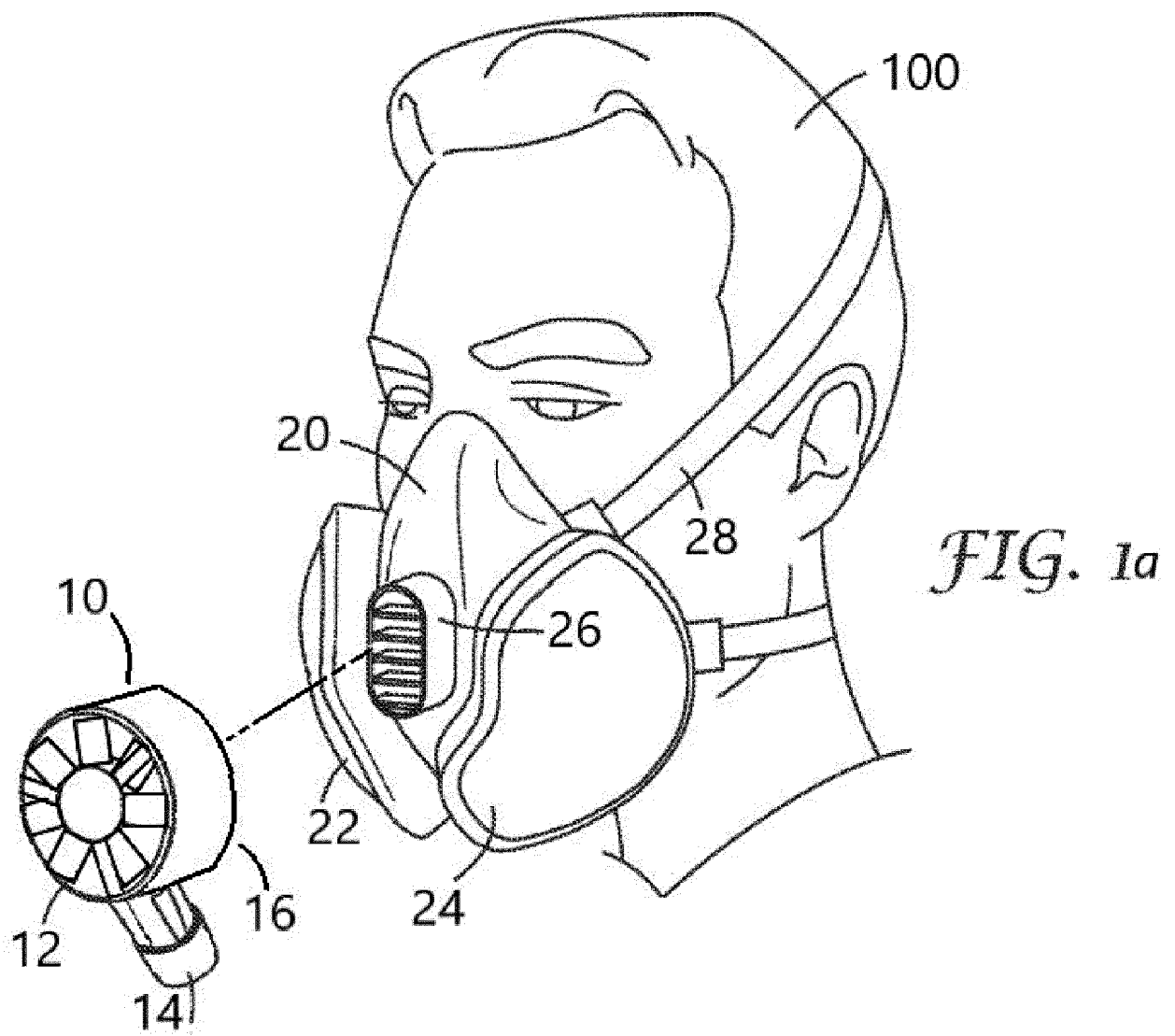
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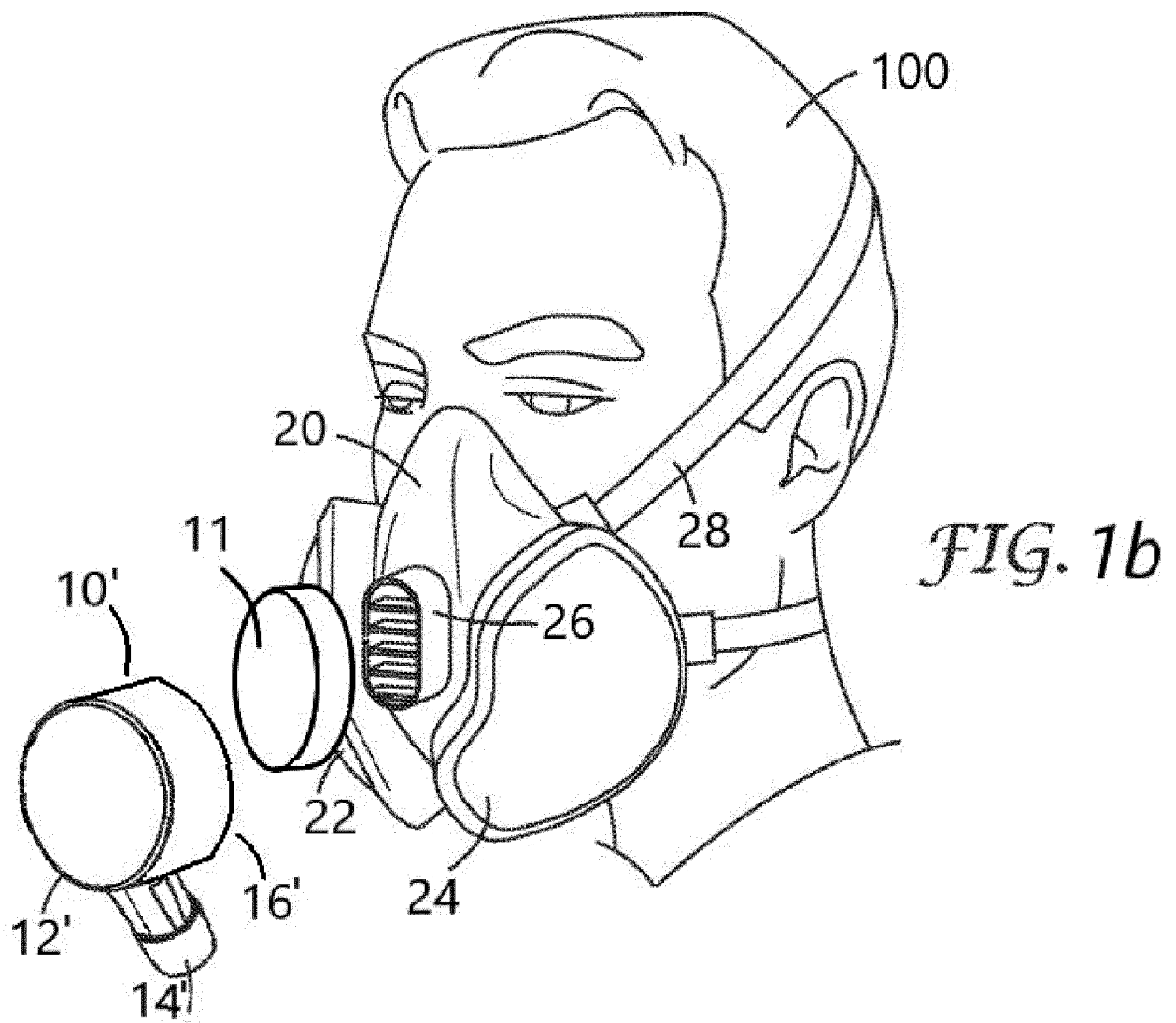
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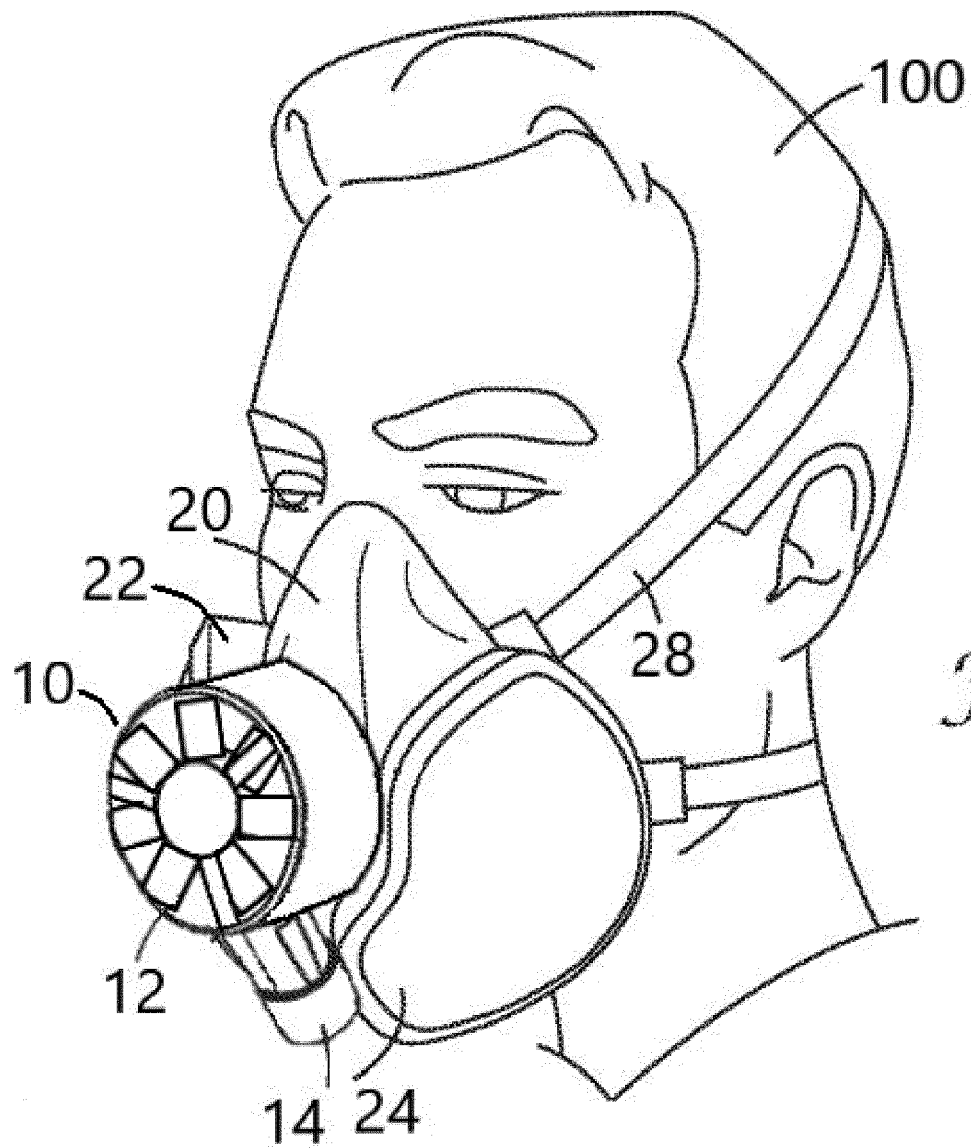


FIG. 2

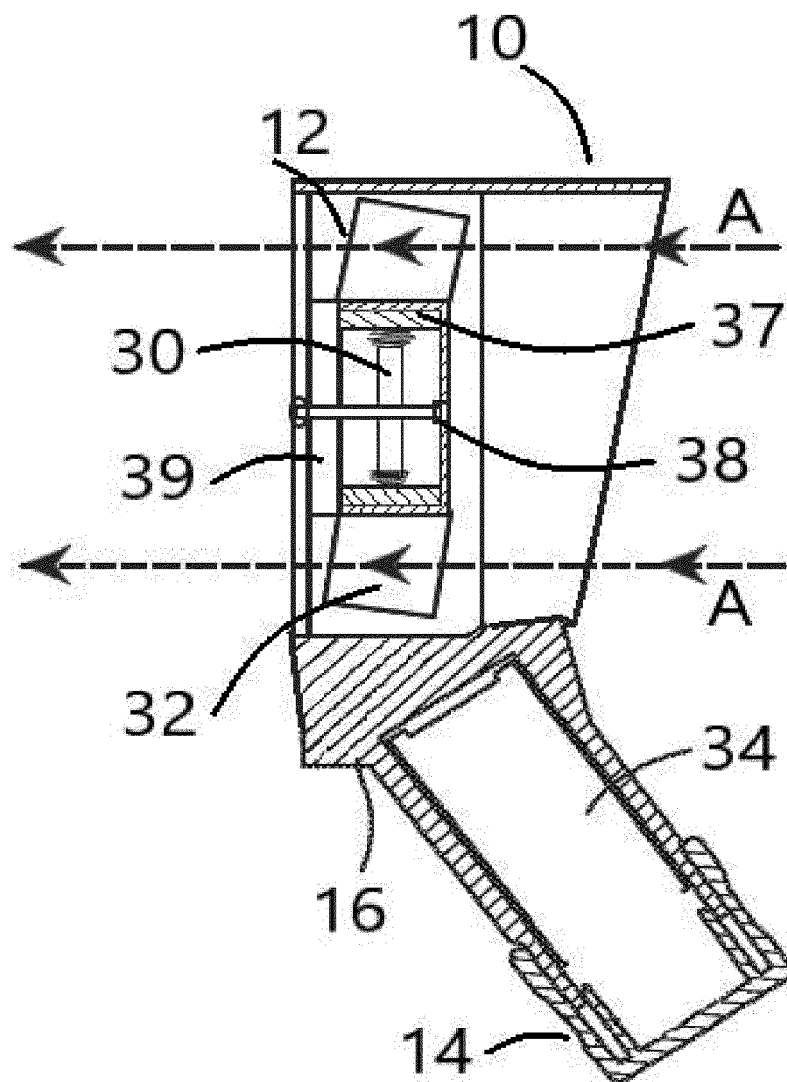


FIG. 3

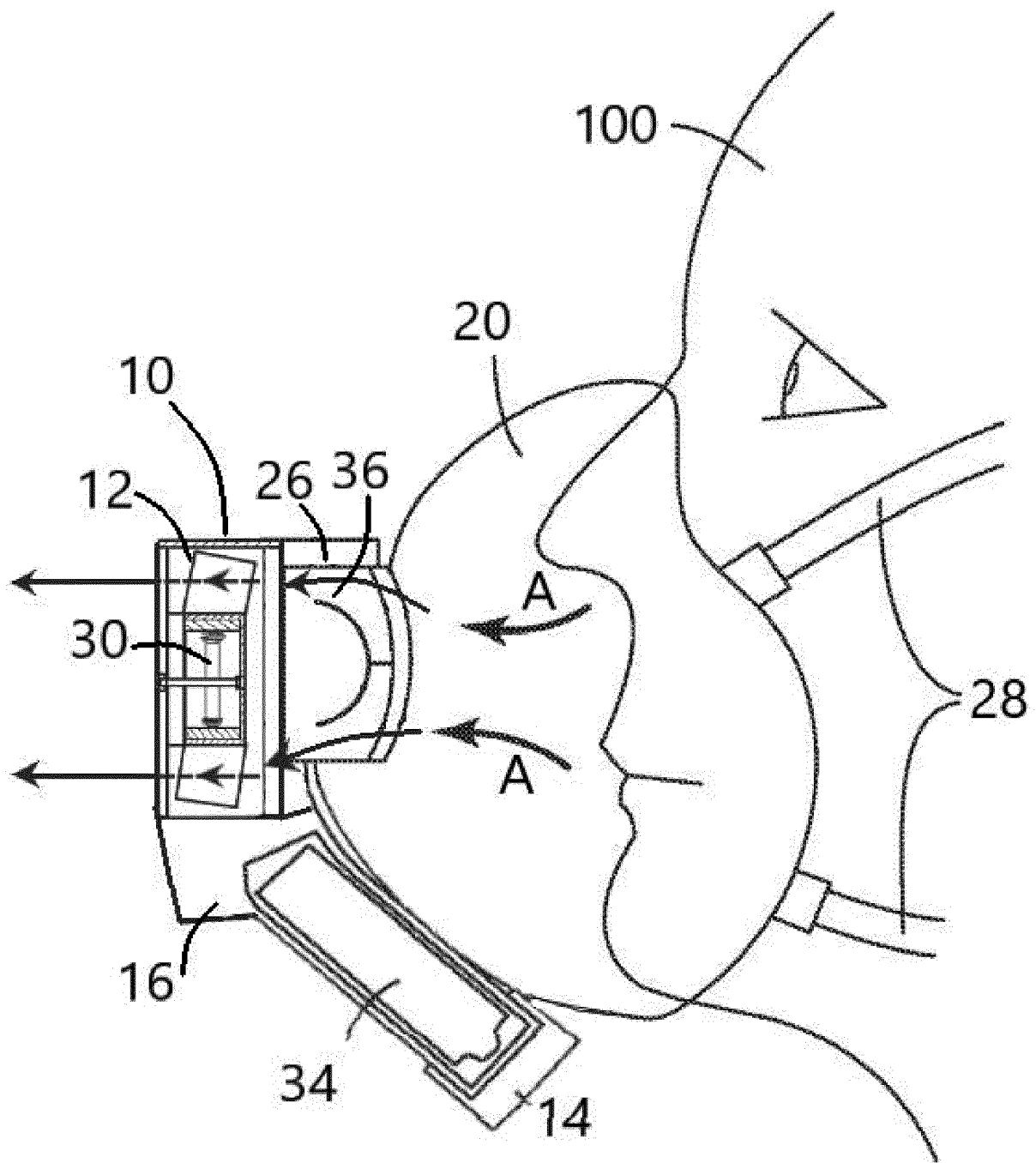
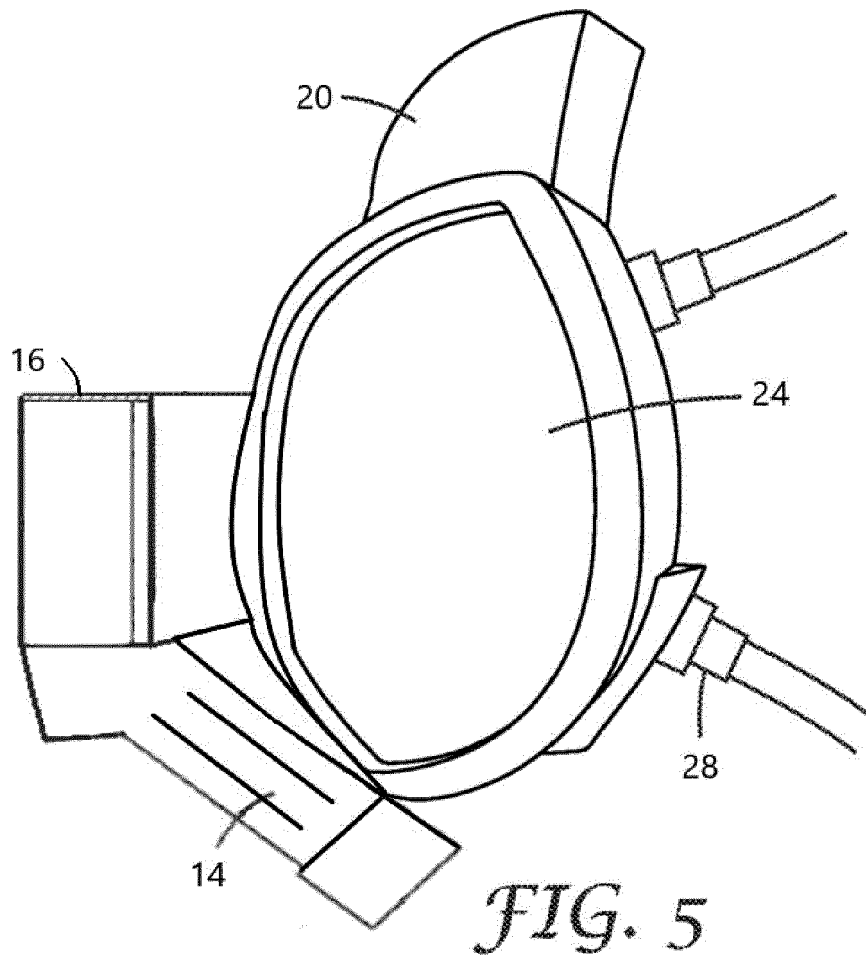


FIG. 4



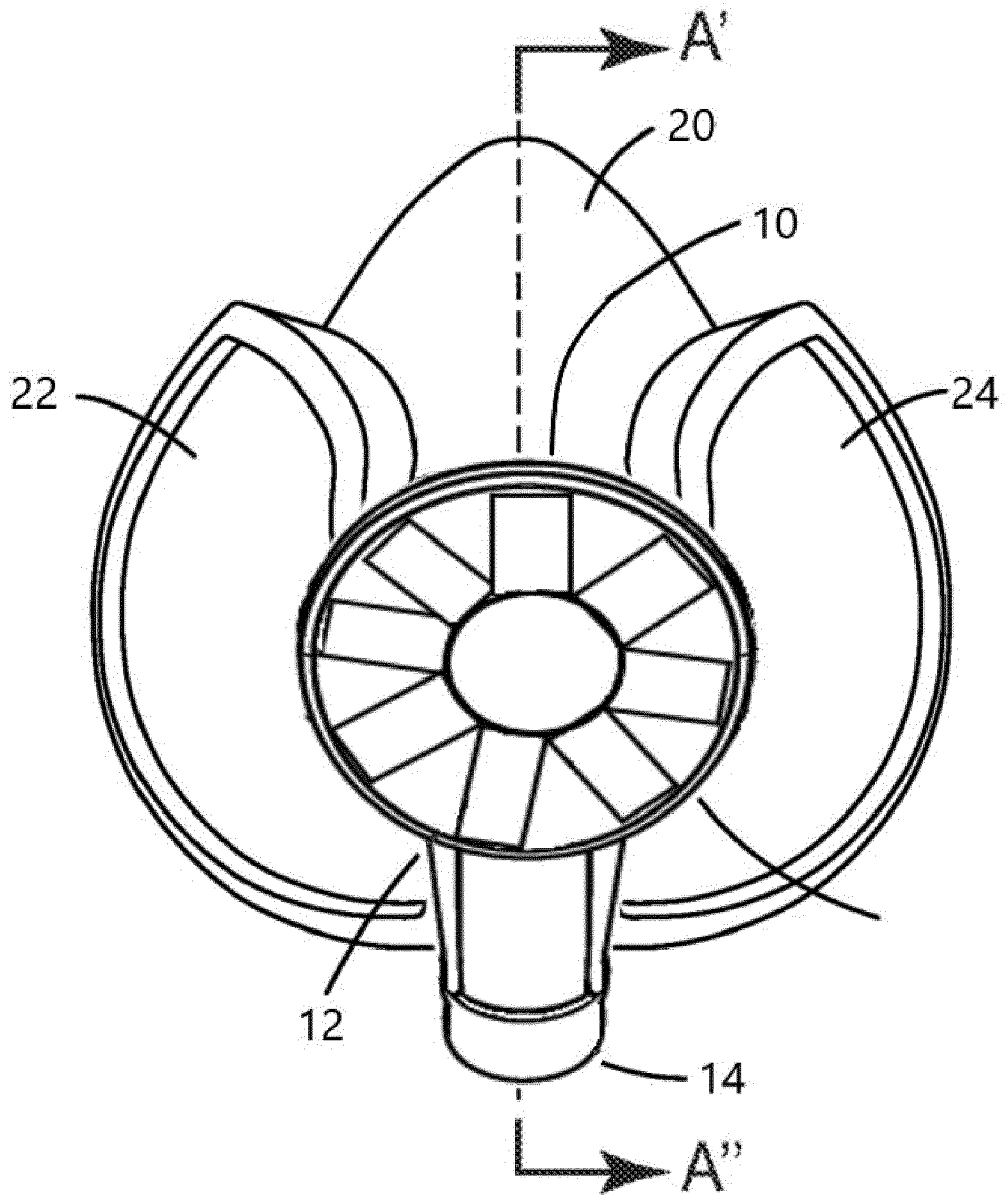


FIG. 6

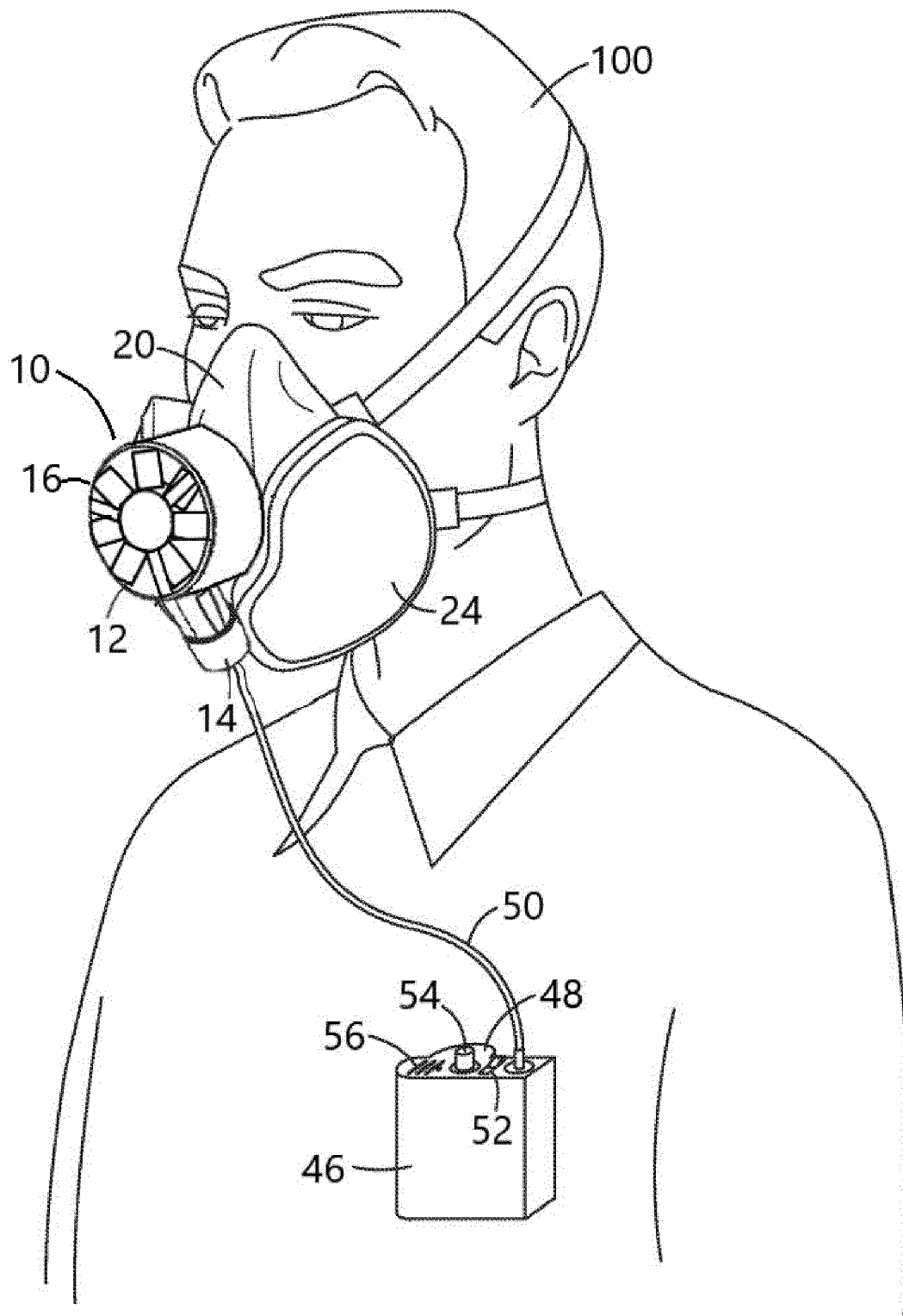


FIG. 7

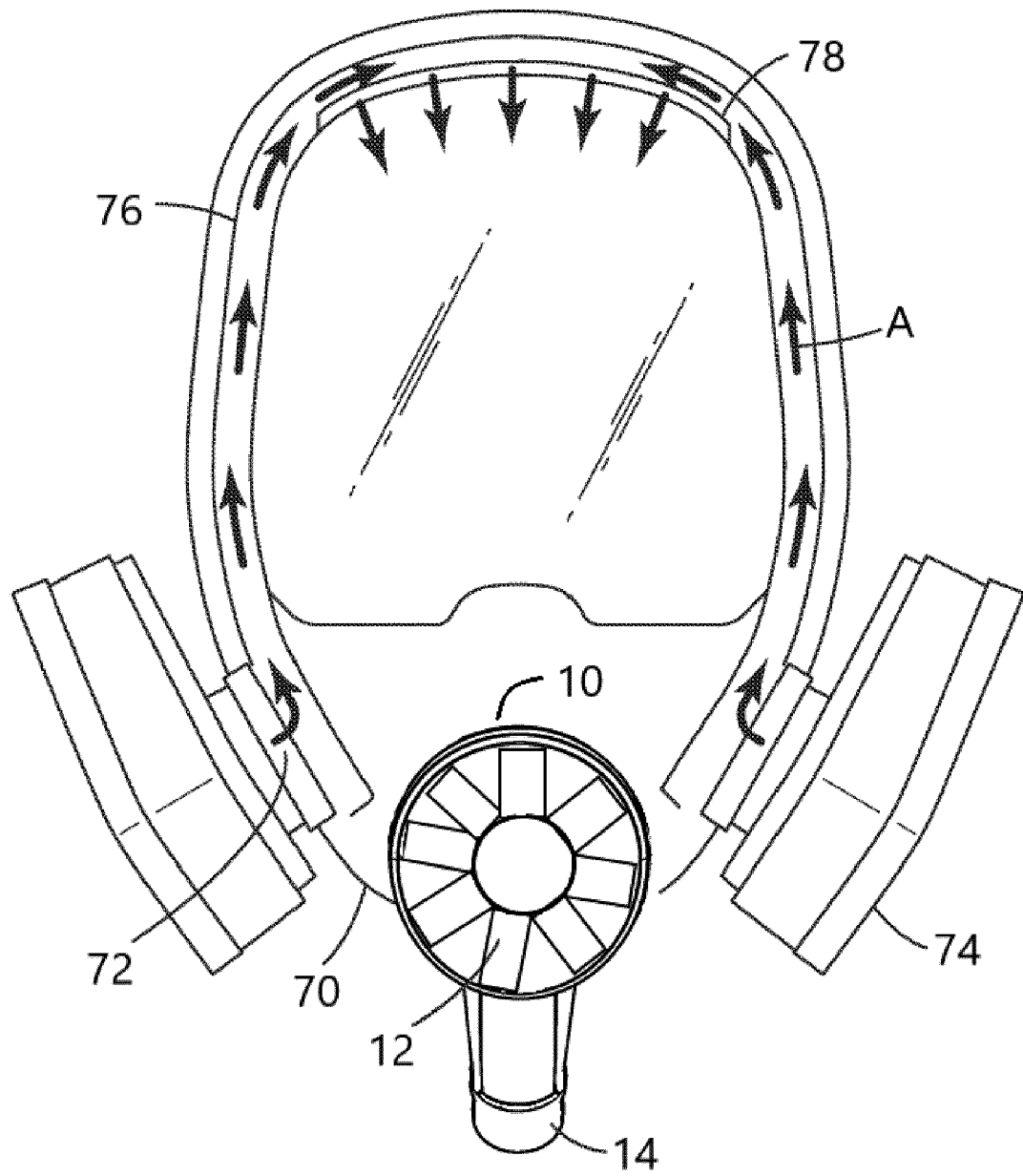


FIG. 8

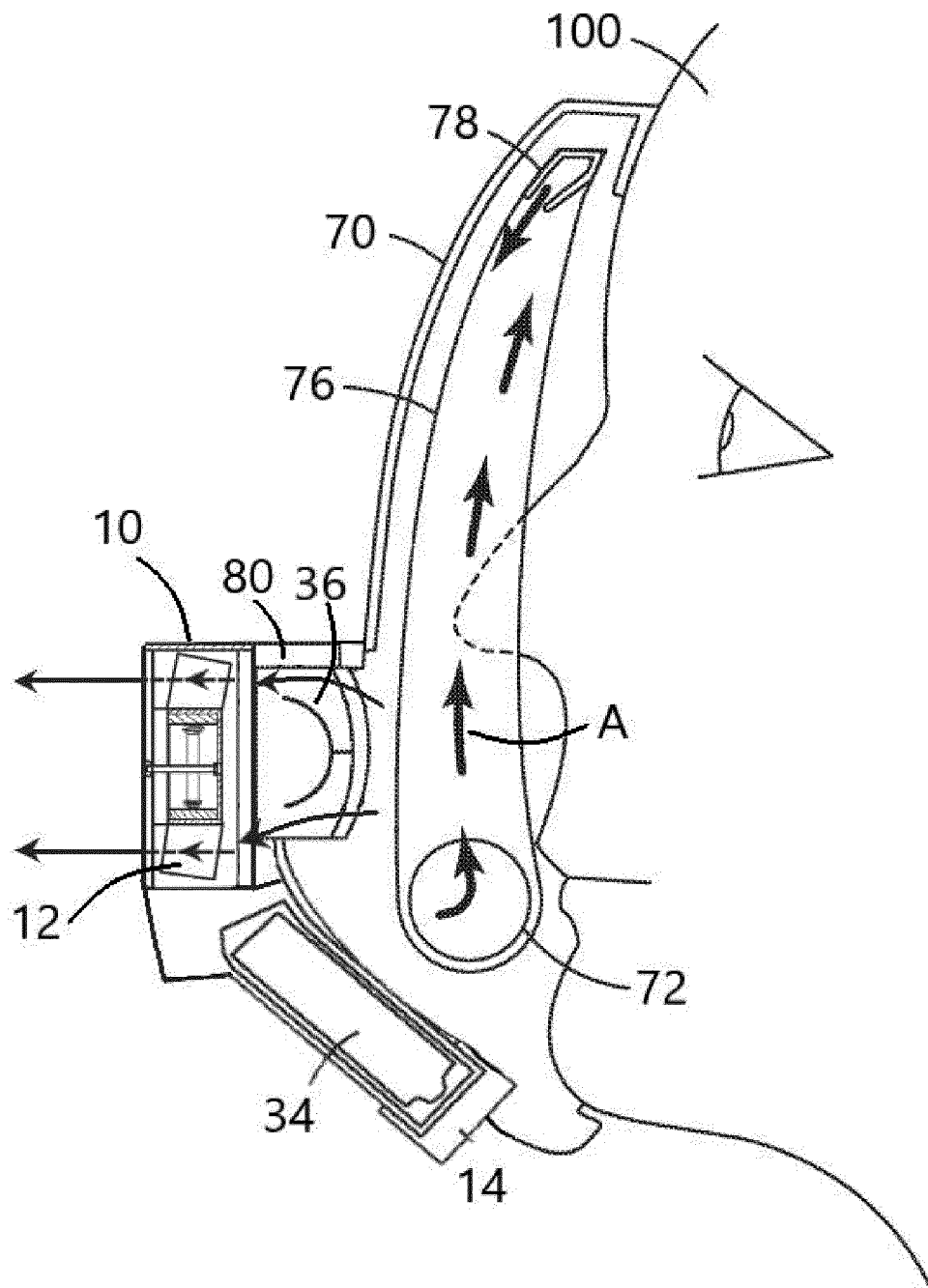
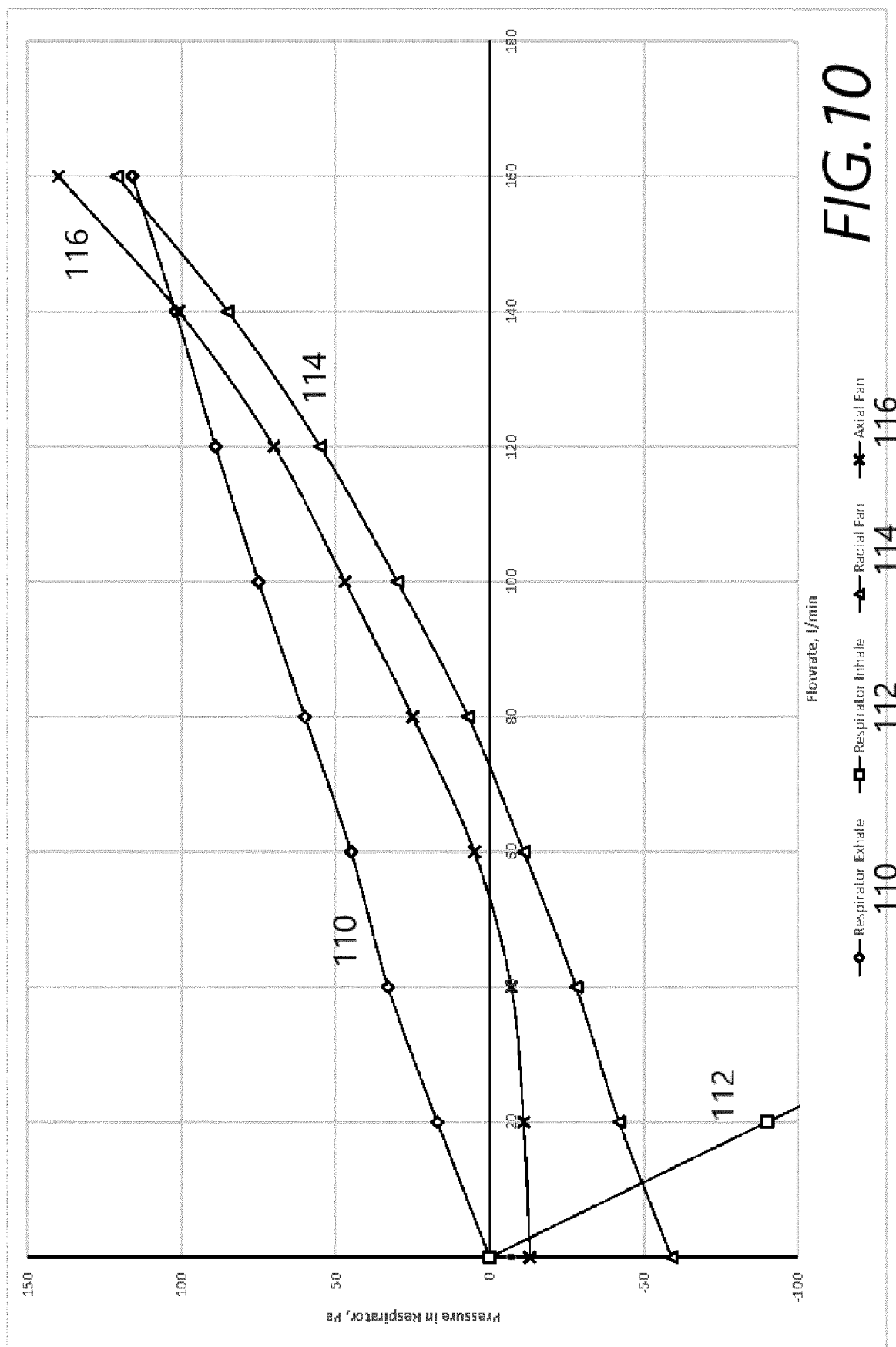


FIG. 9





EUROPEAN SEARCH REPORT

 Application Number
 EP 19 20 0640

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 498 339 A1 (3M INNOVATIVE PROPERTIES CO [US]) 19 June 2019 (2019-06-19) * paragraph [0035] - paragraph [0046] * * paragraph [0057] - paragraph [0063] * * figures 1-17 *	1-15	INV. A62B18/00
X	DE 10 2016 122411 A1 (WEIMA MASCHB GMBH [DE]) 24 May 2018 (2018-05-24) * paragraph [0034] - paragraph [0050] * * figure 1 *	1-7, 11-15 8-10	
A			
			TECHNICAL FIELDS SEARCHED (IPC)
			A62B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 28 February 2020	Examiner Ong, Hong Djien
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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 EPO FORM 1503 03/82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 19 20 0640

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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28-02-2020

10	Patent document cited in search report	Publication date	Patent family member(s)	Publication date
	EP 3498339 A1	19-06-2019	AU 2013309313 A1	19-03-2015
			AU 2016219689 A1	15-09-2016
			BR 112015004105 A2	04-07-2017
15			CA 2882959 A1	06-03-2014
			CN 104780979 A	15-07-2015
			CN 108465172 A	31-08-2018
			EP 2890463 A2	08-07-2015
			EP 3498339 A1	19-06-2019
20			GB 2505484 A	05-03-2014
			JP 6612390 B2	27-11-2019
			JP 2015530148 A	15-10-2015
			JP 2018158128 A	11-10-2018
			KR 20150052143 A	13-05-2015
25			PL 2890463 T3	31-01-2020
			RU 2015108157 A	27-10-2016
			US 2015202473 A1	23-07-2015
			WO 2014035641 A2	06-03-2014

30	DE 102016122411 A1	24-05-2018	NONE	

35				
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45				
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