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## (54) FOLDABLE FACE - PIECE RESPIRATOR OF THE FFP-3 TYPE

(57) A flat-fold filtering face-piece respirator that comprises a mask body having a foldable central portion containing a line of demarcation separating the central portion of the mask body into two portions and along which the central portion can be folded into a collapsed form, said respirator meeting the requirements of the FFP-3 standard.

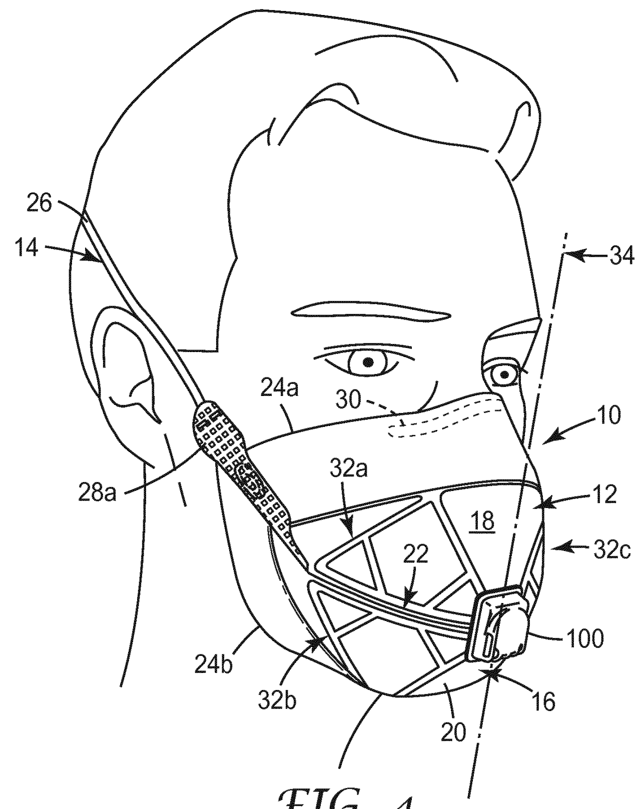


FIG. 4

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## Description

**[0001]** The present disclosure pertains to a foldable filtering face-piece respirators, in particular those with a mask body containing a foldable central portion. Such respirators are suitable for working in an environment with exposure to dust soot or other particles.

## BACKGROUND

**[0002]** Respirators are commonly worn over the breathing passages of a person for at least one of two common purposes: (1) to prevent impurities or contaminants from entering the wearer's breathing track; and (2) to protect other persons or things from being exposed to pathogens and other contaminants exhaled by the wearer. In the first situation, the respirator is worn in an environment where the air contains particles that are harmful to the wearer, for example, in an auto body shop. In the second situation, the respirator is worn in an environment where there is risk of contamination to other persons or things, for example, in an operating room or a clean room.

**[0003]** A variety of respirators have been designed to meet either (or both) of these purposes. Some respirators have been categorized as being "filtering face-pieces" because the mask body itself functions as the filtering mechanism. Unlike respirators that use rubber or elastomeric mask bodies in conjunction with attachable filter cartridges (see, e.g., U.S. Patent RE 39,493 to Yuschak et al.) or insert-molded filter elements (see, e.g., U.S. Patent 4,790,306 to Braun), filtering face-piece respirators are designed to have the filter media cover much of the whole mask body so that there is no need for installing or replacing a filter cartridge. Filtering face-piece respirators commonly come in one of two configurations: molded respirators and flat-fold respirators.

**[0004]** Molded filtering face piece respirators have regularly comprised non-woven webs of thermally-bonded fibers or open-work plastic meshes to furnish the mask body with its cup-shaped configuration. Molded respirators tend to maintain the same shape during both use and storage. Examples of patents that disclose molded, filtering, face-piece respirators include U.S. Patents 7,131,442 to Kronzer et al., 6,923,182, 6,041,782 to Angadjivand et al. , 4,850,347 to Skov, 4,807,619 to Dyrud et al., 4,536,440 to Berg , and Des. 285,374 to Huber et al.

**[0005]** Flat-fold respirators can be folded into a more compact form for shipping and storage and into a cup-shaped form during use as respirator. Examples of flat-fold respirators are shown in U.S. Patents 6,568,392 and 6,484,722 to Bostock et al., in U.S. 6,394,090 to Chen, EP 2 298 419 to Spoo et al.

**[0006]** Flat-fold respirators typically have a mask body that contains a central portion. The central portion, typically is the largest portion of the mask. The central portion typically covers the mouth and at least a part of the nose, at least the nostrils, when donned to the wearer.

**[0007]** In one type of flat-fold respirators, the mask contains portions that can be folded into the central portion or out of the central portion but the central portion retains its shape and is not foldable. Masks of these type typically contain one or more stiffening layers in the central portion that help the central portion retains its shape in the folded and unfolded position.

**[0008]** Another type of flat-fold respirators has a foldable central portion. Masks with a foldable central portion typically contain at least one fold line in the central portion, typically bisecting the central portion into two portions. Such masks typically do not contain stiffening layers, at least not in the central portion.

**[0009]** Respiratory masks are qualified according to their filtering capability into three classes: FFP-1, FFP-2 and FFP-3, with FFP-3 having the strictest requirements.

**[0010]** There is a need to provide flat-fold respirators with a foldable central portion that meet the FFP-3 standards (EN149:2001).

## SUMMARY

### Glossary

**[0011]** The terms set forth below will have the meanings as defined:

"comprises (or comprising)" means its definition as is standard in patent terminology, being an open-ended term that is generally synonymous with "includes", "having", or "containing". Although "comprises", "includes", "having", and "containing" and variations thereof are commonly-used, open-ended terms, this invention also may be suitably described using narrower terms such as "consists essentially of', which is a semi open-ended term in that it excludes only those things or elements that would have a deleterious effect on the performance of the inventive respirator in serving its intended function;

"clean air" means a volume of atmospheric ambient air that has been filtered to remove contaminants;

"contaminants" means particles (including dusts, mists, and fumes) and/or other substances that generally may not be considered to be particles (e.g., organic vapors, et cetera) but which may be suspended in air;

"crosswise dimension" is the dimension that extends laterally across the respirator from side-to-side when the respirator is viewed from the front;

"cup-shaped configuration" means any vessel-type shape that is capable of adequately covering the nose and mouth of a person;

"exterior gas space" means the ambient atmospheric gas space into which exhaled gas enters after passing through and beyond the mask body and/or exhalation valve;

"filtering face-piece" means that the mask body itself is designed to filter air that passes through it; there are no separately identifiable filter cartridges or in-

sert-molded filter elements attached to or molded into the mask body to achieve this purpose;
"filter" or "filtration layer" means one or more layers of air-permeable material, which layer(s) is adapted for the primary purpose of removing contaminants (such as particles) from an air stream that passes through it;
"filtering structure" means an air-permeable structure that is designed to remove contaminants from air that passes through it. The filtering structure contains a filtration layer or a plurality thereof.
"first side" means an area of the mask body that is located on one side of a plane that bisects the mask body normal to the cross-wise dimension;
"fitment" means any one or combination of donning, doffing, or the adjusting mask body;
"flange" means a protruding part that has sufficient surface area to be grasped by a person;
"frontally" means extending away from the mask body perimeter when the mask body is in a folded condition;
"harness" means a structure or combination of parts that assists in supporting the mask body on a wearer's face;
"indicia" means an identifying mark(s), pattern(s), image(s), opening(s), or combination thereof;
"integral" means being manufactured together at the same time; that is, being made together as one part and not two separately manufactured parts that are subsequently joined together;
"interior gas space" means the space between a mask body and a person's face;
"laterally" means extending away from a plane that bisects the mask body normal to the cross-wise dimension when the mask body is in a folded condition;
"line of demarcation" means a fold, seam, weld line, bond line, stitch line, hinge line, and/or any combination thereof;
"longitudinal axis" means a line that bisects the mask body normal to the cross-wise dimension;
"mask body" means an air-permeable structure that is designed to fit over the nose and mouth of a person and that helps define an interior gas space separated from an exterior gas space (including the seams and bonds that join layers and parts thereof together);
"nose clip" means a mechanical device (other than a nose foam), which device is adapted for use on a mask body to improve the seal at least around a wearer's nose;
"perimeter" means the outer edge of the mask body, which outer edge would be disposed generally proximate to a wearer's face when the respirator is being donned by a person;
"pleat" means a portion that is designed to be or is folded back upon itself;
"polymeric" and "plastic" each mean a material that mainly includes one or more polymers and that may contain other ingredients as well;
"plurality" means two or more;
"respirator" means an air filtration device that is worn by a person to provide the wearer with clean air to breathe;
"second side" means an area of the mask body that is located on one side of a plane that bisects the mask body normal to the cross-wise dimension (the second side being opposite the first side);
"snug fit" or "fit snugly" means that an essentially air-tight (or substantially leak-free) fit is provided (between the mask body and the wearer's face);
"tab" means a part that exhibits sufficient surface area for attachment of another component; and
"transversely extending" means extending generally in the crosswise dimension.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]**

FIG. 1 is a perspective schematic view of a flat-foldable filtering face-piece respirator with a foldable central panel containing an optional exhalation valve.
FIG. 2 is a schematic front view of the respirator shown in FIG. 1.
FIG. 3 is a schematic front view of the respirator of FIG. 1 in a folded condition.
FIG. 4 is a schematic perspective view of a flat-foldable filtering face-piece respirator that is a preferred embodiment of the present disclosure and contains structural patterns.
FIG. 5 is a cross-section of the filtering structure 16.

## DETAILED DESCRIPTION

**[0013]** The present disclosure provides a flat-fold filtering face-piece respirator construction. In filtering face-piece respirators the mask body itself is designed to filter air that passes through it; they do not contain separate filter cartridges or insert-molded filter elements attached to or molded into the mask body to achieve this purpose. Flat-fold filtering face-piece respirators can be folded into a cup-shaped form for use and in a more compact form for storage or transportation. Such respirators comprises a mask body that contains foldable portions and the respirator according to the present invention contains a foldable central portion. The central portion of the mask body is the portion that covers the mouth and at least a part of the nose, at least the nostrils, when donned to the wearer. In a single panel mask, the mask only contains a central portion and the central portion form the mask body. In this case the central portion is large enough to fit over the nose and mouth of a person and defines an interior gas space separated from an exterior gas space (including the seams and bonds that join layers and parts thereof together). In other embodiments the mask body contains includes the central portion and one or more other portions that can be folded into and folded out of the central portion. The central portion of the masks according to the present invention itself is foldable and it may or may not contain other portions that can be folded into and out of it. The central portion contains a line of demarcation which separates the central portion into two, preferably essentially equal, portions. Essentially equal means the portions may be of equal size or may be of similar size and one portion may have up to twice the size of the other portion, or where one portion has up to and including 1.5 times the size of the other portion, or up to and including 1.1 times the size of the other portion.

**[0014]** The line of demarcation may divide the central portion into a lower or upper portion, or into a left and right portion. The line of demarcation may be a fold, a seam or a weld line and may support collapse resistance of the mask body. Preferably, the line of demarcation allows at least parts of the two portions of the central portion to be folded along the line of demarcation. In one particular embodiment the line of demarcation is a fold. The central portion preferably is single piece onto which the line of demarcation is created. However, in some embodiments the line of demarcation joins two separate portions to form the central portion, for example it may be a stitched line or weld line joining two pieces together to form a one-piece but foldable central portion.

**[0015]** An exhalation valve may be placed in the central portion of the mask body when viewed from the front such that the exhalation valve is positioned essentially over the wearer's mouth when the mask is donned. Positioned essentially over the wearer's mouth as used herein means it is positioned over the wearer's mouth or in proximity to the wearer's mouth, meaning in the area between the wearer's nose and chin when the respirator is being donned. The valve may be placed on the line of demarcation, in which case the line of demarcation may be discontinuous. It may be interrupted at the location of the exhalation valve to allow the valve to function as an exhalation valve. The optional exhalation valve may also be placed on another position of the central panel, for example next to the line of demarcation of at a distance to it.

**[0016]** The mask body of the present disclosure may further comprise a first and a second additional panel joint to the central portion by a foldable connection, for example a pleat or a fold line.

**[0017]** The line of demarcation may extend transversely and separates the central portion of the mask body into an upper and a lower portions. Such a mask body may further comprise an upper additional panel joint to the upper portion of the central portion by a foldable connection, for example a pleat or a fold line such that the additional panel can be folded into at least a part of the upper portion of the central portion of the mask body. Such a mask body may also or in addition contain an additional lower panel joint to the lower portion of the central portion of the mask body by a foldable connection, for example a pleat or a fold line such that it can be folded into at least parts of the lower portion of the mask body.

**[0018]** The line of demarcation may extend longitudinally and separates the central portion of the mask body into a left and a right portion (when viewed from the front). Such a mask body may further comprise an upper additional panel joint to the upper portion of the central portion of the mask body by a foldable connection, for example a pleat or a fold line such that the additional panel can be folded into at least a part of the upper portion of the central portion of the mask body. Such a mask body may also or in addition contain an additional lower panel joint to the lower portion of the central portion of the mask body by a foldable connection, for example a pleat or a fold line such that it can be folded into at least parts of the lower portion of the central portion of the mask body.

**[0019]** The mask body and preferably the central portion of the mask body may contain one or more than one structural lines. Such structural lines provide additional stability to the mask body. Such lines include weld lines and seams. Weld lines typically compress the fibers in the filtering structure such that they become mostly solidified into a nonporous solid-type bond. The structural lines may be about 2 to 7 mm wide, more commonly about 4 to 5 mm wide. If the filtering structure comprises more than one layer, these layers essentially become merged together at the base of the weld line.

**[0020]** The structural line or a plurality thereof may run in a parallel, diagonal or orthogonal direction with respect to the line of demarcation. In a preferred embodiment structural lines are arranged to form a structural pattern, preferably, in proximity to the exhalation valve or connected to the exhalation valve. Preferably both portions of the mask body contain a structural pattern. The valve may be located within a structural pattern or between several structural patterns, preferably connecting these patterns. In a preferred embodiment, both portions of the mask body contain several structural patterns and the exhalation valve is placed at a conjunction of two or more structural patterns.

**[0021]** In another embodiment the respirator according to the present disclosure does not contain any structural patterns because the line of demarcation provides sufficient structural stability, or the line of demarcation and one or two or more additional lines provide sufficient structural stability. Such lines may arranged in parallel to each other or not parallel to each other.

**[0022]** The disclosure will now be described in greater detail by referring to the drawings without intending to limit the disclosure the drawings and combination of features shown in the drawings. Not all features or combination of features shown in the drawings are necessarily essential features to practice the disclosure.

**[0023]** FIG. 1 shows a schematic illustration of a flat-fold filtering face-piece respirator according to the invention in an opened condition on a wearer's face. The respirator may be used in accordance with the present disclosure to provide clean air for the wearer to breathe. As illustrated, the filtering face-piece respirator includes a mask body 10, an optional harness 14, and optional exhalation valve 100, and optional upper and lower panels 161, 162. The harness 14 has a strap 26 that is attached (here: stapled) to a flange 28a (and another flange 28 b on the other side of the mask (not shown in figure 1). The flanges may be as described, for example, in international patent application WO2010/080201.

**[0024]** The mask body 10 has a central portion 12. The central portion covers the mouth and the nostrils when donned. The central portion or panel contains a filtering structure 16 through which inhaled air must pass before entering the wearer's respiratory system. The filtering structure 16 removes contaminants from the ambient environment so that the wearer breathes clean air. The filtering structure and central portion may be identical (i.e. the entire central portion is a filtering structure) or the central portion may only contain segments that form a filtering structure.

**[0025]** The central portion 12 of the mask body 10 contains a line of demarcation 22 separating the central portion 12 of the mask body 10 into a first portion 18 (here illustrated as top portion) and a second portion 20 (here illustrated as bottom portion). The central portion 12 can be folded along the line of demarcation 22 into a more compact version of the mask for storage. The central portion preferably is a single piece onto which the line of demarcation is applied to make the central portion foldable along that line. In one embodiment, also less preferred, the central portion is formed by at least two individual pieces, for example the upper and lower portions, or left and right portions, which may be joint together through the line of demarcation 22 to form the central panel 12.

**[0026]** The first portion 18 of the central portion 12 of the mask body 10 and/or the second portion 20 may be connected to an additional first panel (161) and/or an additional second panel (162) respectively, which are an upper and a lower panel in the embodiment illustrated in FIG. 1. The upper and lower panels may be connected to the central portion 12 (made up of lower and upper portions 18, 20) of the mask body 10 in a foldable manner. Alternatively or in addition, pleats may be connected to the first and second portions 18, 20 of the central portion 12 or to the first and second additional panel 161, 162.

**[0027]** The lower portion 20 of the central portion 12 may include more or the same filter media surface area than the upper portion 18. The mask body 12 may also include a perimeter web 54 that is secured to the mask body along its perimeter (not shown in Fig 1). The perimeter web 54 may be folded over the mask body at the perimeter 24a, 24b. The perimeter web 54 also may be an extension of the inner cover web 58 folded and secured around the edge of 24a and 24b. The nose clip 30 may be disposed on the upper portion of the mask body centrally adjacent to the perimeter 24a. The nose clip 30 may be made from a pliable dead soft metal or plastic that is capable of being manually adapted by the wearer to fit the contour of the wearer's nose. The nose clip may be made from aluminum and may be linear or it may take on other shapes when viewed from the top such as the m-shaped nose clip shown in U.S. Patents 5,558,089 and Des. 412,573 to Castiglione.

**[0028]** An optional exhalation valve 100 is placed in the central area of the central portion 12 of the mask body 10 on the line of demarcation 22 of the embodiment illustrated in figure 1. The line of demarcation 22 may be interrupted at the location of valve or sufficiently discontinued such that air can pass from the interior gas phase through the valve to the exterior. The mask body 10 also includes a perimeter that includes an upper segment 24a and a lower segment 24b.

**[0029]** An optional nose clip 30 may be placed on the mask body 10, for example.

**[0030]** The line of demarcation 22 of the embodiment illustrated in FIG.1 extends transversely across the central portion of the mask body and separates the central portion into an upper portion 18 and a lower portion 20. In another embodiment of the masks according to the invention, not illustrated in Fig. 1, the line of demarcation 22 extends longitudinally across the central portion 12 and separates the central portion into a left and a right portion.

**[0031]** FIG. 2 shows the respirator 10 of FIG.1 from the front and FIG. 3 illustrates the respirator in its collapsed or folded condition, which condition is particularly beneficial for shipping and off-the-face storage.

**[0032]** FIG 4 illustrates an embodiment of the present disclosure showing a respirator as shown in Fig. 1 with the mask body additionally having a structural pattern. The structural pattern may be made up of lines, for example seams, or weld lines. Typically, the lines are 2 to 7 mm are wide, more commonly about 4 to 5 mm wide. Preferably the structural pattern is a weld pattern. The structural pattern illustrated in FIG 4 is made up by a set of lines forming triangles. Preferably, the structural pattern does not traverse the line of demarcation 22. The structural pattern illustrated in FIG 4 comprises first and second structural patterns 32a, 32c, preferably weld patterns, disposed in the first portion 18 of the central portion and not traversing the line of demarcation 22. It contains the first and second weld patterns 32a, 32c on each side of the longitudinal axis 34. The mask illustrated in FIG. 4 also has a third 32b and fourth structural pattern 32d in the lower portion 20 of the central portion 12 and on each side of the longitudinal axis 34. The third and fourth weld patterns 32b and 32d are disposed below and not crossing the line of demarcation 22 (the fourth pattern 32 d not being visible in FIG 4). Each weld pattern may exhibit a truss-type geometry that includes, for example, a larger triangle that has rounded corners and that has a pair of triangles located within it. Each of the triangles may be nested within the larger triangle 32a-32d such that the two sides of each of the triangles also forms a partial side of each of the triangles 32a-32d. Preferably, as shown in FIG. 4 , the weld patterns 32a-32d are provided on the central portion 12 such that there is symmetry on each side of the of the line of demarcation 22, and preferably also on each side of the axis perpendicular to the line of demarcation, which in the embodiment illustrated in FIG. 4 is the longitudinal axis 34. Although the structural pattern has been illustrated in the present drawings as being triangular patterns the two-dimensional enclosed patterns may take on other truss-type forms, including quadrilaterals that are, rectangular, trapezoidal, rhombusal, etc., which are welded or stitched into the mask body. The structural pattern may be an enclosed pattern or may also be a non-enclosed pattern. Alternative patterns include but are not limited to a plurality of straight or curved lines parallel and/or orthogonal to the line of demarcation 22.

**[0033]** In case of the structural pattern being a two-dimensional enclosed weld pattern, it may occupy a surface area of about 5 to 30 square centimeters ($cm^2$), more commonly about 10 to 16 $cm^2$.

**[0034]** The respirator illustrated in FIG. 4 has a front view analogue to that shown in FIG. 2 and can be collapsed or folded as illustrated in FIG. 3.

**[0035]** FIG. 5 illustrates that the filtering structure 16 of the respirators according to the present disclosure may include one or more layers such as an inner cover web 58, an outer cover web 60, and a filtration layer 62. The inner and outer cover webs 58 and 60 may be provided to protect the filtration layer 62 and to preclude fibers from the filtration layer 62 from coming loose and entering the mask interior. During respirator use, air passes sequentially through layers 60, 62, and 58 before entering the mask interior. The air that is disposed within the interior gas space of the mask may then be inhaled by the wearer. When a wearer exhales, the air passes in the opposite direction sequentially through layers 58, 62, and 60. An optional exhalation valve (not shown in Fig. 5) may be provided on the mask body to allow exhaled air to be rapidly purged from the interior gas space to enter the exterior gas space without passing through filtering structure 16. Typically, the cover webs 58 and 60 are made from a selection of nonwoven materials that provide a comfortable feel, particularly on the side of the filtering structure that makes contact with the wearer's face. The construction of various filter layers and cover webs that may be used in conjunction with the support structure of the present invention are described below in more detail. To improve wearer fit and comfort, an elastomeric face seal can be secured to the perimeter of the filtering structure 16. Such a face seal may extend radially inward to contact the wearer's face when the respirator is being donned. Examples of face seals are described in U.S. Patents 6,568,392 to Bostock et al., 5,617,849 to Springett et al., and 4,600,002 to Maryyanek et al., and in Canadian Patent 1,296,487 to Yard.

**[0036]** The mask body that is used in connection with the present disclosure may take on a variety of different shapes and configurations. Generally the shape and configuration of the filtering structure corresponds to the general shape of the mask body or at least to the central portion of the mask body. Although a filtering structure has been illustrated in Fig. 5 with multiple layers that include a filtration layer and two cover webs, the filtering structure may simply comprise a single filtration layer or a combination of several filtration layers. A pre-filter may be disposed upstream to a more refined and selective downstream filtration layer. Additionally, sorptive materials such as activated carbon may be disposed between the fibers and/or various layers that may comprise the filtering structure. Further, separate particulate filtration layers may be used in conjunction with sorptive layers to provide filtration for both particulates and vapors.

**[0037]** Preferably, the filtering structure and more preferably the central portion does not include any stiffening layer. Stiffening layers are layers of materials that do not remove particles but are used to retain the shape of the filtering layer or central portion.

**[0038]** The respiratory masks according to the present disclosure meets the FFP-3 standard (EN 149:2001). The filtering structure of the respiratory masks of the present invention has a layer containing filter material (filtration layer). The layer containing the filter material may be a single layer or it may be a combination of several layers. The maximum thickness of the filtration layer (be it a single layer or a combination of layers) is 1.6 mm, preferably 1.1 mm. Typical thickness of the layer containing the filter material (single layer or combination of layers) is between 0.7 and 1.6 mm, preferably between 0.8 and 1.2 mm. The thickness of the filter material can be measured by placing the sample under a digital height gauge (typically an average of 10 samples is taken).

**[0039]** It was found that flat-fold respirators with a foldable central portion perform having a filtration layer with a thickness as described above perform better under the fit test than masks with thicker filtration layers. Such masks may adapt better to the shape of the wearer than masks with identical cover webs but thicker filtration layers.

**[0040]** The filtering structure that is used in a mask body of the present disclosure is of a particle capture type filter. The filtering structure also may be a barrier layer that prevents the transfer of liquid from one side of the filter layer to another to prevent, for instance, liquid aerosols or liquid splashes (e.g. blood) from penetrating the filtration layer. Multiple layers of similar or dissimilar filter materials may be used to construct the filtration layer of the invention. Examples of filter materials that capture particles include one or more webs of fine inorganic fibers (such as fiberglass) or polymeric synthetic fibers. Synthetic fiber webs may include electret-charged polymeric microfibers that are produced from processes such as meltblowing. Polyolefin microfibers formed from polypropylene that has been electrically charged provide particular utility for particulate capture applications. An alternate filtration layer may comprise a sorbent component for removing hazardous or odorous gases from the breathing air. Sorbents may include powders or granules that are bound in a filtration layer by adhesives, binders, or fibrous structures - see U.S. Patents 6,334,671 to Springett et al. and 3,971,373 to Braun. A sorbent layer can be formed by coating a substrate, such as fibrous or reticulated foam, to form a thin coherent layer. Sorbent materials may include activated carbons that are chemically treated or not, porous alumna-silica catalyst substrates, and alumna particles. An example of a sorptive filtration structure that may be conformed into various configurations is described in U.S. Patent 6,391,429 to Senkus et al.

**[0041]** The filtration material may be a generally planar web or it could be corrugated to provide an expanded surface area - see, for example, U.S. Patents 5,804,295 and 5,656,368 to Braun et al. The filtration layer also may include multiple filtration layers joined together by an adhesive or any other means. Webs of melt-blown fibers, especially when in a persistent electrically charged (electret) form are especially useful (see, for example, U.S. Pat. No. 4,215,682 to Kubik et al.). Preferably, the melt-blown fibers are microfibers that have an effective fiber diameter less than about 20 micrometers ($\mu$m) (referred to as BMF for "blown microfiber"), preferably between 5 and 10 $\mu$m. Effective fiber diameter may be determined according to Davies, C. N., The Separation Of Airborne Dust Particles, Institution Of Mechanical Engineers, London, Proceedings 1B, 1952 . Particularly preferred are BMF webs that contain fibers formed from polypropylene, poly(4-methyl-1-pentene), and combinations thereof. Electrically charged fibrillated-film fibers also may be suitable, as well as rosin-wool fibrous webs and webs of glass fibers or solution-blown, or electrostatically sprayed fibers, especially in microfilm form. Electric charge can be imparted to the fibers by contacting the fibers with water as disclosed, for example, in U.S. Patents 6,824,718 to Eitzman et al., 6,783,574 to Angadjivand et al., 6,743,464 to Insley et al., 6,454,986 and 6,406,657 to Eitzman et al., and 6,375,886 and 5,496,507 to Angadjivand et al. Electric charge also may be imparted to the fibers by corona charging as disclosed in U.S. Patent 4,588,537 to Klasse et al. or by tribocharging as disclosed in U.S. Patent 4,798,850 to Brown. Also, additives can be included in the fibers to enhance the filtration performance of webs produced through the hydrocharging process (see U.S. Patent 5,908,598 to Rousseau et al.). Fluorine atoms, in particular, can be disposed at the surface of the fibers in the filter layer to improve filtration performance in an oily mist environment - see U.S. Patents 6,398,847 B1, 6,397,458 B1, and 6,409,806 B1 to Jones et al.

**[0042]** The filtration layer, typically a web of fibers that may or may not contain additives, has a pressure drop from 2.0 to 8.0, preferably from 4.2 to 5.6 mm $H_2O$. It may also have a penetration value of 0.1 to 0.5 %. Pressure drop and penetration were measured on a commercially available automated filter tester (AFT8130 from TSI Inc.). Tests were done with a paraffin oil aerosol, at an air flow rate of 50 liters per minute.

**[0043]** The filtration layer, preferably a fiber web, preferably has a basis weight from 0.70 g to 1.10 g. The basis weight is determined by weighing samples punched from the filter web material using a 5.25" circular punch. 10 samples were taken and the results were averaged. The weight can be converted into g/m$^2$ by multiplying the weight by 71.6 (i.e. a basis weight of 0.70 g to 1.10 g translates into a basis weight of about 50 to 87 g/m$^2$ (or gsm, gram per square meters).

**[0044]** The filtration material may be covered in the filtering structure on one side by a cover web, preferably the filtration material is covered by a cover web on its opposite side.

**[0045]** An inner cover web can be used to provide a smooth surface for contacting the wearer's face, and an outer cover web can be used to entrap loose fibers in the mask body or for aesthetic reasons. The cover web typically does not provide any substantial filtering benefits to the filtering structure, although it can act as a pre-filter when disposed on the exterior (or upstream to) the filtration layer. To obtain a suitable degree of comfort, an inner cover web preferably has a comparatively low basis weight and is formed from comparatively fine fibers. More particularly, the cover web may be fashioned to have a basis weight of about 5 to 50g/m$^2$ (typically 10 to 30g/m$^2$), and the fibers may be less than 3.5 denier (typically less than 2 denier, and more typically less than 1 denier but greater than 0.1). Fibers used in the cover web often have an average fiber diameter of about 5 to 24 micrometers, typically of about 7 to 18 micrometers, and more typically of about 8 to 12 micrometers. The cover web material may have a degree of elasticity (typically, but not necessarily, 100 to 200% at break) and may be plastically deformable. Suitable materials for the cover web may be blown microfiber (BMF) materials, particularly polyolefin BMF materials, for example polypropylene BMF materials (including polypropylene blends and also blends of polypropylene and polyethylene). A suitable process for producing BMF materials for a cover web is described in U.S. Patent 4,013,816 to Sabee et al. The web may be formed by collecting the fibers on a smooth surface, typically a smooth-surfaced drum or a rotating collector - see U.S. Patent 6,492,286 to Berrigan et al. Spun-bond fibers also may be used.

**[0046]** A typical cover web may be made from polypropylene or a polypropylene/polyolefin blend that contains 50 weight percent or more polypropylene. These materials have been found to offer high degrees of softness and comfort to the wearer and also, when the filter material is a polypropylene BMF material, to remain secured to the filter material without requiring an adhesive between the layers. Polyolefin materials that are suitable for use in a cover web may include, for example, a single polypropylene, blends of two polypropylenes, and blends of polypropylene and polyethylene, blends of polypropylene and poly(4-methyl-1-pentene), and/or blends of polypropylene and polybutylene. One example of a fiber for the cover web is a polypropylene BMF made from the polypropylene resin "Escorene 3505G" from Exxon Corporation, providing a basis weight of about 25 g/m$^2$ and having a fiber denier in the range 0.2 to 3.1 (with an average, measured over 100 fibers of about 0.8). Another suitable fiber is a polypropylene/polyethylene BMF (produced from a mixture comprising 85 percent of the resin "Escorene 3505G" and 15 percent of the ethylene/alpha-olefin copolymer "Exact 4023" also from Exxon Corporation) providing a basis weight of about 25 g/m$^2$ and having an average fiber denier of about 0.8. Suitable spunbond materials are available, under the trade designations "Corosoft Plus 20", "Corosoft Classic 20" and "Corovin PP-S-14", from Corovin GmbH of Peine, Germany, and a carded polypropylene/viscose material available, under the trade designation "370/15", from J.W. Suominen OY of Nakila, Finland.

**[0047]** The outer cover web may be of the same materials and composition as described above for the inner cover web or it may be made from the same materials but have a different composition, for example it may differ in thickness and or density. Cover webs that are used in the present disclosure preferably have very few fibers protruding from the web surface after processing and therefore have a smooth outer surface. Examples of cover webs that may be used in the present disclosure are disclosed, for example, in U.S. Patent 6,041,782 to Angadjivand, U.S. Patent 6,123,077 to Bostock et al., and WO 96/28216A to Bostock et al.

**[0048]** The strap(s) that are used in the harness may be made from a variety of materials, such as thermoset rubbers, thermoplastic elastomers, braided or knitted yarn/rubber combinations, inelastic braided components, and the like. The strap(s) may be made from an elastic material such as an elastic braided material. The strap preferably can be expanded to greater than twice its total length and be returned to its relaxed state. The strap also could possibly be increased to three or four times its relaxed state length and can be returned to its original condition without any damage thereto when the tensile forces are removed. The elastic limit thus is preferably not less than two, three, or four times the length of the strap when in its relaxed state. Typically, the strap(s) are about 20 to 30 cm long, 3 to 10 mm wide, and about 0.9 to 1.5 mm thick. The strap(s) may extend from the first tab to the second tab as a continuous strap or the strap may have a plurality of parts, which can be joined together by further fasteners or buckles. For example, the strap may have first and second parts that are joined together by a fastener that can be quickly uncoupled by the wearer when removing the mask body from the face. An example of a strap that may be used in connection with the present invention is shown in U.S. Patent 6,332,465 to Xue et al. Examples of fastening or clasping mechanism that may be used to joint one or more parts of the strap together is shown, for example, in the following U.S. Patents 6,062,221 to Brostrom et al, 5,237,986 to Seppala, and EP1,495,785A1 to Chien.

**[0049]** Following are some non-limiting embodiments of the present disclosure:

Embodiment 1. A flat-fold filtering face-piece respirator that comprises a mask body having a foldable central portion containing a line of demarcation separating the central portion of the mask body into two portions and along which the central portion can be folded into a collapsed form, said respirator meeting the requirements of the FFP-3 standard.

Embodiment 2. The respirator of Embodiment 1 wherein the line of demarcation bisects the central portion of the mask body into two portions of essentially equal size.

Embodiment 3. The respirator of any of the preceding Embodiments wherein the line of demarcation is selected from a weld line, a seam or a fold.

Embodiment 4. The respirator of any of the preceding Embodiments wherein the line of demarcation extends transversely and the two portions are an upper and a lower portion.

Embodiment 5. The respirator of any of the preceding Embodiments wherein the line of demarcation extends longitudinally and separates the central portion into a left and a right portion.

Embodiment 6. The respirator of any of the preceding Embodiments wherein the mask body further comprises a structural pattern.

Embodiment 7. The respirator of any of the preceding Embodiments wherein the mask body further comprises a structural pattern comprising a first and a second weld pattern, wherein the first and second weld patterns are disposed in the central portion of the mask body but are not traversing the line of demarcation.

Embodiment 8. The respirator of any of the preceding Embodiments wherein the mask body further comprises a structural pattern comprising a first and a second weld pattern, wherein the first and second weld patterns are disposed in the central portion of the mask body but are not traversing the line of demarcation and wherein each weld pattern comprises one or more triangles.

Embodiment 9. The respirator of any of the preceding Embodiments wherein the mask body further comprises a structural pattern and wherein the structural pattern occupies an area of about 5 to 30 cm2.

Embodiment 10. The respirator of any of the preceding Embodiments further comprising an exhalation valve.

Embodiment 11. The respirator of any of the preceding Embodiments wherein the mask body further comprises a structural pattern and an exhalation valve and wherein the exhalation valve is positioned within the structural pattern.

Embodiment 12. The respirator of any of the preceding Embodiments wherein the mask body further comprises a structural pattern and wherein the structural pattern is made up of lines selected from weld lines, seams and stitch lines, and wherein each line is about 2 to 7 mm thick.

Embodiment 13. The respirator of any of the preceding Embodiments wherein at least the central portion of the mask body comprises a filtration layer comprising a fiber web having a maximum thickness of from 0.7 to 1.6 mm, preferably from 0.8 to 1.2 mm.

Embodiment 14. The respirator of any of the preceding Embodiments wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm, preferably from 0.8 to 1.2 mm and wherein the filtration layer has a pressure drop from 2.0 to 8.0, preferably from 4.2 to 5.6 mm H2O and a penetration of 0.1 to 0.5 % (as measured on a commercially available automated filter tester (AFT8130 from TSI Inc., tests done with a paraffin oil aerosol, at an air flow rate of 50 liters per minute).

Embodiment 15. The respirator of any of the preceding Embodiments wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm, preferably from 0.8 to 1.2 mm and wherein the filtration layer has a basis weight from about 50 to 87 g/m$^2$.

Embodiment 16. The respirator of any of the preceding Embodiments wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm, preferably from 0.8 to 1.2 mm and wherein the filtration layer comprises a fiber web comprising fibers that comprise a polypropylene homo- or copolymer.

Embodiment 17. The respirator of any of the preceding Embodiments wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm and a basis weight between 50 and 87 g/m$^2$ and comprises a fiber web comprising fibers that comprise a polypropylene homo- or copolymer.

Embodiment 18. The respirator of any of the preceding Embodiments wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm and a basis weight between 50 and 87 g/m$^2$ and comprises a fiber web comprising fibers that comprise a polypropylene homo- or copolymer and wherein the filtration layer has a pressure drop from 2.0 to 8.0, preferably from 4.2 to 5.6 mm H2O and a penetration of 0.1 to 0.5 % (as measured on a commercially available automated filter tester (AFT8130 from TSI Inc., tests done with a paraffin oil aerosol, at an air flow rate of 50 liters per minute).

Embodiment 19. The respirator of any of the preceding Embodiments wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm and a basis weight between 50 and 87 g/m$^2$ and comprises a fiber web comprising fibers that comprise a polypropylene homo- or copolymer and wherein the filtration layer has a pressure drop from 2.0 to 8.0, preferably from 4.2 to 5.6 mm H2O and a penetration of 0.1 to 0.5 % (as measured on a commercially available automated filter tester (AFT8130 from TSI Inc., tests done with a paraffin oil aerosol, at an air flow rate of 50 liters per minute) and wherein the filtration layer is placed between at least one out cover web facing away from the wearer when the mask is donned and at least one inner web facing the wearer when donned.

**[0050]** This disclosure may take on various modifications and alterations without departing from its spirit and scope. Accordingly, this invention is not limited to the above-described but is to be controlled by the limitations set forth in the following claims and any equivalents thereof. This invention also may be suitably practiced in the absence of any element not specifically disclosed herein.

**[0051]** All patents and patent applications cited above, including those in the Background section, are incorporated by reference into this document in total. To the extent there is a conflict or discrepancy between the disclosure in such incorporated document and the above specification, the above specification will control.

EXAMPLE

**[0052]** Filter material in the form of fiber webs according to the present invention can be prepared as known in the art, for example as described in US 2008/0011303 A1.

**[0053]** Masks according to the present invention can be prepared as described in EP 2 298 419 A1. Specifically, the masks can be prepared according to the following procedure.

**[0054]** A respirator filtering structure was formed from three layers of nonwoven material and other respirator components. The inventive mask was assembled in two operations - preform making and mask finishing. The preform making stage included the steps of lamination and fixing of nonwoven fibrous webs, formation of pleat crease lines and attachment of perimeter web material and nose clip. The mask finishing operation included folding of pleats along embossed crease lines, fusing both the lateral mask edges and reinforced flange material, cutting the final form, and attaching a headband.

Preform Making Stage

**[0055]** In the preform making stage, three layers of nonwoven material were plied in face to face orientation. In the example, individual materials that formed the layers were assembled in the following order: 1. outer cover web; 2. filter material; 3. inner cover web.

**[0056]** As outer cover web (indicated as 60 in FIG. 5) a 17 grams per square meter (gsm) polypropylene spunbonded nonwoven, available from Shandong Kangjie Nonwovens Co. Ltd., Jinan, China can be used. The inner cover web (indicated as 58 in FIG. 5) can be of the same material as the outer scrim. The filter material (indicated as 60 in FIG. 5) as described in the description can be used. The preform can be made by plying, in the desired order, layers of each material that is then cut into 20 cm by 33 cm sheets and ultrasonically welded together using a point-bonded pattern. Reinforcing weld patterns can be formed into the body of the preform as desired (for example as described in EP 2 298 419 A1 "prefrom making stage"). With the layers of nonwoven fixed, crease lines that define pleat location can be embossed on the fixed layers of nonwoven. Embossing of the crease lines can be done using a die cutting machine, Hytronic Cutting Machine Model B, from USM Corporation, Haverhill, Massachusetts, at 15 tons of force and with a rule die. The die had nine bars with radius edges that traversed the length of the preform and when pressed into the preform created lines into the nonwoven layers. The embossed lines compressed the webs together at the point of contact and did not fuse or penetrate the material.

**[0057]** As a final step in the preform making operation, bands of perimeter web, (for example BBA Nonwovens, 51 grams per square meter (gsm) spun-bonded polypropylene scrim, 4 cm wide and 36 cm long) can be wrapped around the top and bottom edges of the preform and ultrasonically welded into place. Ultrasonic welding can be carried out using an ultrasonic welding unit, for example Model 2000X from Branson, Danbury, Connecticut, operated at a ram pressure of 448 kPa with a horn amplitude, frequency, and dwell time of 100%, 20 kHz, and 0.5 sec, respectively. A nose clip can be attached to the top of the preform and encapsulated between the preform and the perimeter web. The nose clip can be a malleable, plastically-deformable aluminum strip, for example 9 cm long by 0.5 cm wide by 1 mm thick.

Mask Finishing Operation

**[0058]** In the mask finishing operation, pleats can be folded along crease lines (for example as shown in FIG. 5. of EP2 298 419 A1). Pleats located above the central fold of the mask, can be folded such that the exterior folds face downwards with the mask open. This can be done to help prevent accumulation of gross matter in the mask folds when worn. With the preform pleated and folded around the center fold, the preform can be ultrasonically welded to fuse the lateral edges of the mask and to create the bonded layers of the stiffening flange (28a and 28b in FIG. 1). Ultrasonic welding can be done, for example, using an ultrasonic welding unit Model 2000ae from Branson, Danbury, Connecticut, operated at a ram pressure of 483 kPa with a horn amplitude, frequency, and dwell time of 100%, 20kHz, and 2.0 sec, respectively. Angled bar elements of the anvil seal the lateral edges of the mask and pin welding surfaces fuse and stiffen the flange material. As a final step in the mask finishing operation, the stiffening flanges are cut to a desired shape and a headband can be stapled to the tabs.

**[0059]** Masks were prepared according to the general procedure described above and tested for FFP-3 criteria. In a first series of masks (comparative example 1) two layers of a filter web were used. Each layer of filter web had a thickness of about 1.06 mm and the total thickness was about 2.1 mm. Each layer of filter web had a pressure drop between 3.5 and 4.9 mm $H_2O$, and a penetration between 3.5 and 7.5 %. The mask met the FFP-3 standard. In a second series of masks (example 1) the same cover webs and processes were used except that only a single filter web used as filter material. The filter web had a thickness between 0.8 and 1.2 mm, a pressure drop between 4.2 and 5.6 mm H2O, and penetration between 0.2 and 0.5 % (Pressure drop and penetration tests were done with paraffin oil aerosol on an automated filter tester, AFT8301 from TSI Inc., at a flow rate of 50 L /min). The filter web had a basis weight between 50 and 87 gsm and an effective fiber diameter of between 5 and 7 $\mu$m. Also this series of masks passed the FFP-3 test. Masks of example 1 and comparative example 1 were subjected to a fit test. Masks of example 1 performed better than masks of comparative example 1. The fit test measures how well a mask fits to the face. The fit test can be carried out, for example using a quantitative respirator fit tester (8038 PortaCount Pro Respirator Fit Tester from TSI Inc.), using a panel of 25 people.

## Claims

1. A flat-fold filtering face-piece respirator that comprises a mask body having a foldable central portion containing a line of demarcation separating the central portion of the mask body into two portions and along which the central portion can be folded into a collapsed form, said respirator meeting the requirements of the FFP-3 standard.

2. The respirator of claim 1 wherein the line of demarcation bisects the central portion of the mask body into two portions of essentially equal size.

3. The respirator of any of the preceding claims wherein the line of demarcation is selected from a weld line, a seam or a fold.

4. The respirator of any of the preceding claims wherein the line of demarcation extends transversely and the two portions are an upper and a lower portion.

5. The respirator of any of the preceding claims wherein the line of demarcation extends longitudinally and separates the central portion into a left and a right portion.

6. The respirator of any of the preceding claims wherein the mask body further comprises a structural pattern.

7. The respirator of any of the preceding claims wherein the mask body further comprises a structural pattern

comprising a first and a second weld pattern, wherein the first and second weld patterns are disposed in the central portion of the mask body but are not traversing the line of demarcation.

**8.** The respirator of any of the preceding claims wherein the mask body further comprises a structural pattern comprising a first and a second weld pattern, wherein the first and second weld patterns are disposed in the central portion of the mask body but are not traversing the line of demarcation and wherein each weld pattern comprises one or more triangles.

**9.** The respirator of any of the preceding claims wherein the mask body further comprises a structural pattern and wherein the structural pattern occupies an area of about 5 to 30 $cm^2$.

**10.** The respirator of any of the preceding claims runner comprising an exhalation valve.

**11.** The respirator of any of the preceding claims wherein the mask body further comprises a structural pattern and an exhalation valve and wherein the exhalation valve is positioned within the structural pattern.

**12.** The respirator of any of the preceding claims wherein the mask body further comprises a structural pattern and wherein the structural pattern is made up of lines selected from weld lines, seams and stitch lines, and wherein each line is about 2 to 7 mm thick.

**13.** The respirator of any of the preceding claims wherein at least the central portion of the mask body comprises a filtration layer comprising a fiber web having a maximum thickness of from 0.7 to 1.6 mm, preferably from 0.8 to 1.2 mm.

**14.** The respirator of any of the preceding claims wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm, preferably from 0.8 to 1.2 mm and wherein the filtration layer has a pressure drop from 2.0 to 8.0, preferably from 4.2 to 5.6 mm $H_2O$ and a penetration of 0.1 to 0.5 % (as measured on a commercially available automated filter tester (AFT8130 from TSI Inc., tests done with a paraffin oil aerosol, at an air flow rate of 50 liters per minute).

**15.** The respirator of any of the preceding claims wherein at least the central portion of the mask body comprises a filtration layer having a maximum thickness of from 0.7 to 1.6 mm, preferably from 0.8 to 1.2 mm and wherein the filtration layer has a basis weight from about 50 to 87 $g/m^2$.

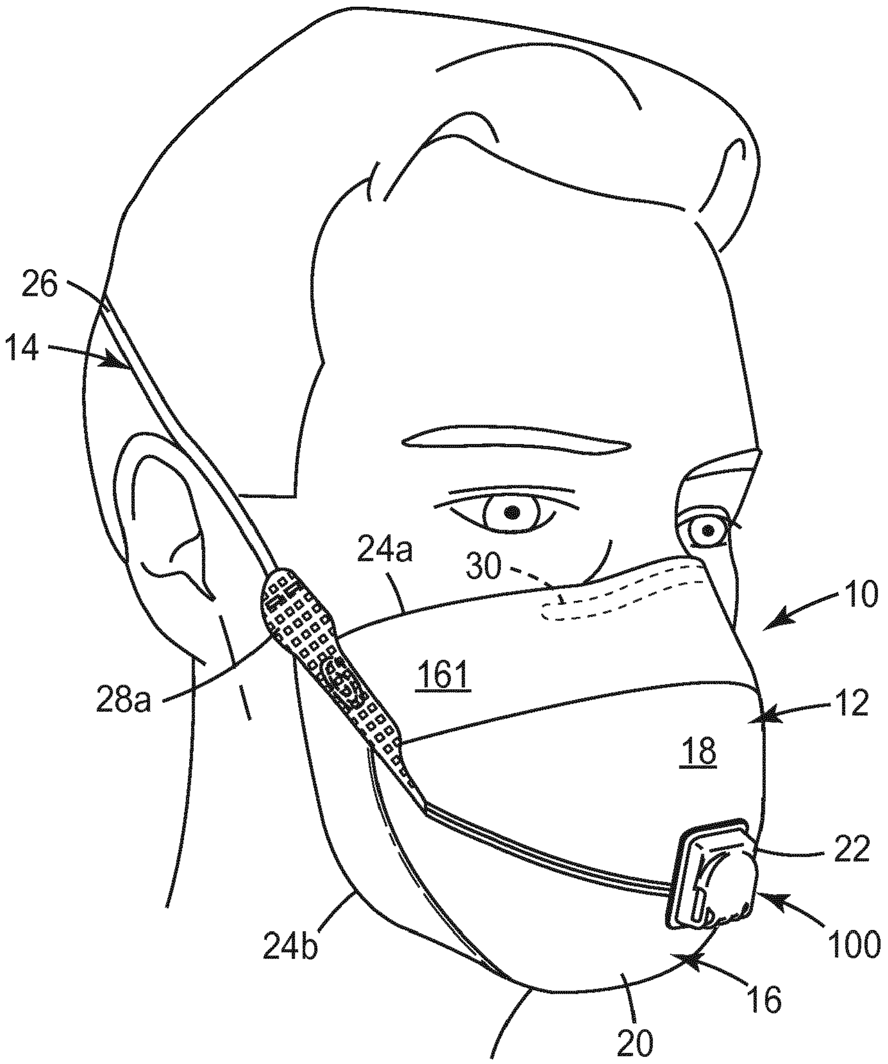


FIG. 1

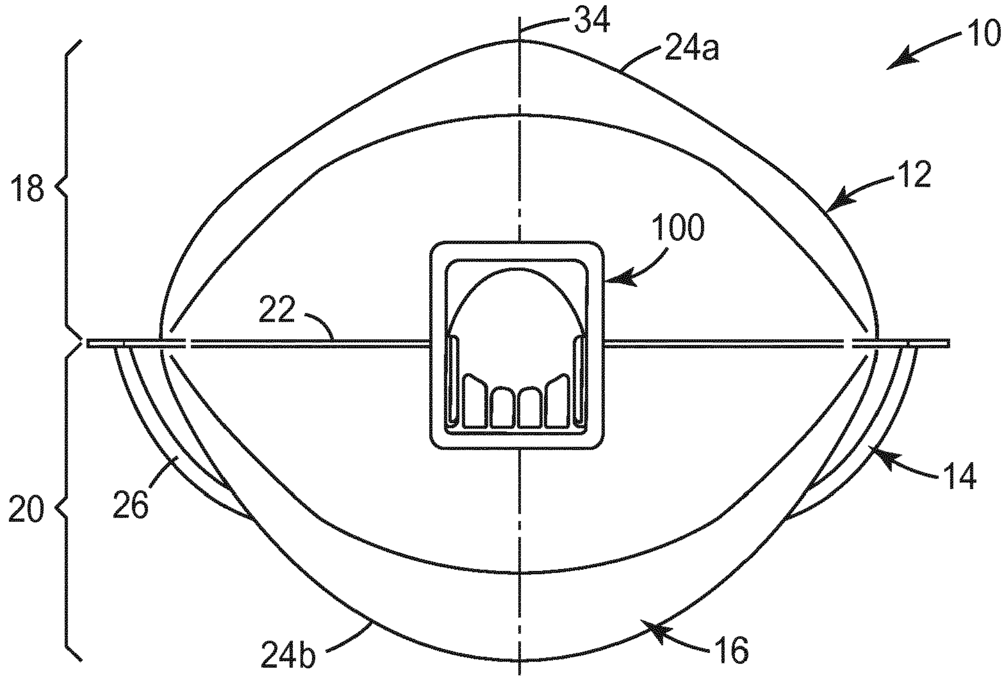


FIG. 2

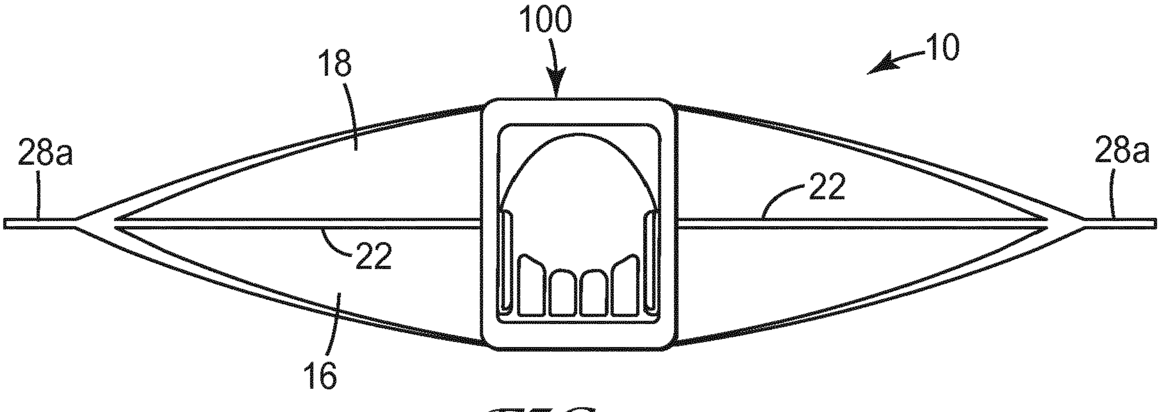


FIG. 3

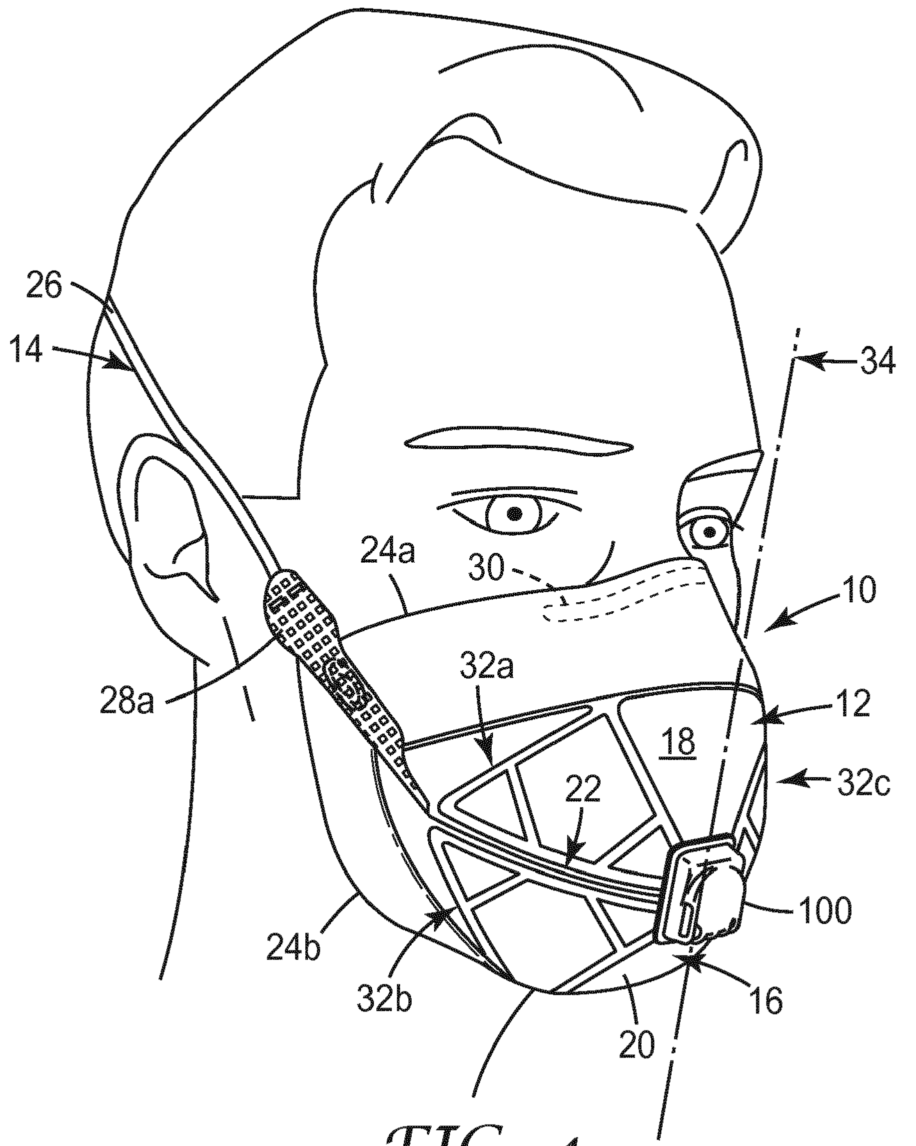


FIG. 4


FIG. 5

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Application Number
EP 18 16 1813

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