United States Patent

Reimschussel et al.

[15] **3,688,768**

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[54] **DISPOSABLE FACE RESPIRATOR AND METHOD OF MAKING SAME**

[72] Inventors: **George Paul Reimschussel**, Flemington, N.J.; **Jacob Matthys Prins**, Sinking Spring, Pa.

[73] Assignee: **Johns-Manville Corporation**, New York, N.Y.

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[52] **U.S. Cl.** 128/146.2

[51] **Int. Cl.** A62b 23/00

[58] **Field of Search**.....128/146.2, 146, 146.3–146.7, 128/142.6, 140 R, 139; 2/3–9, 206; 162/218, 219, 231

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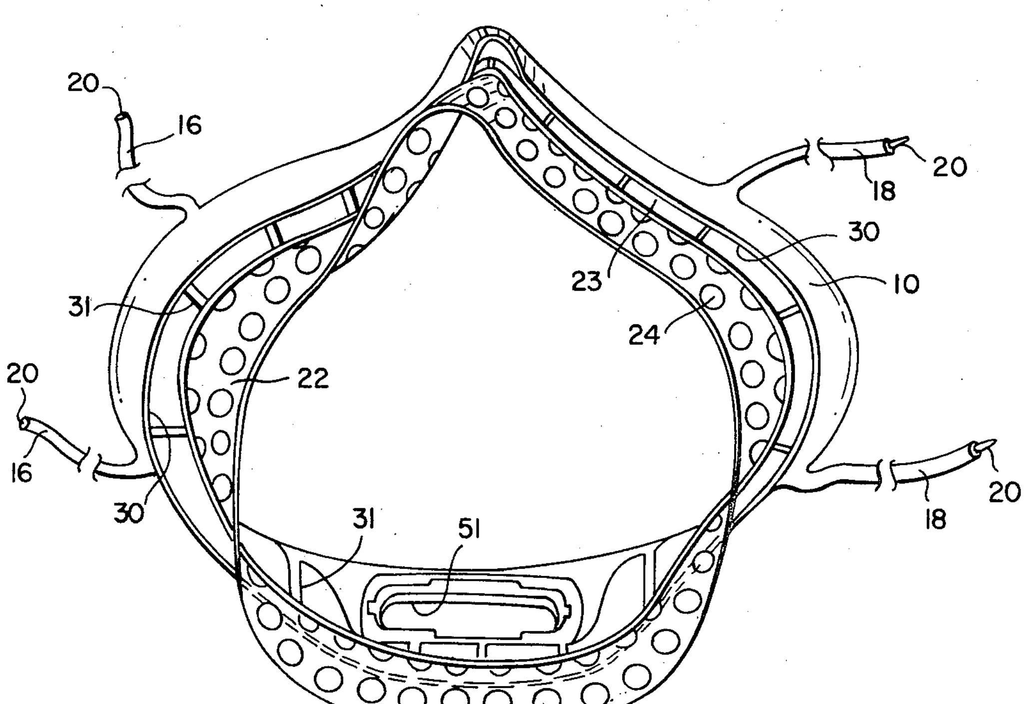
Primary Examiner—Richard A. Gaudet
Assistant Examiner—J. B. Mitchell
Attorney—John A. McKinney, Robert M. Krone, Joseph J. Kelly and Ronald M. Halvorsen

[57] **ABSTRACT**

A disposable face respirator formed of a shape retaining filter medium comprised of a plurality of fibrous layers that cover a major portion of the surface area of the mask and a flexible face piece attached to the periphery of the filter medium. An improved filter medium to face piece sealing joint is provided by incorporating an apertured lip on the face piece which is interlocked between first and second fibrous layers with the fibers in the second fibrous layer extending into and contacting fibers in the first fibrous layer. An undercut area may be provided in the apertured lip into which fibers which form the filter layer can be drawn.

A process of simultaneously forming and attaching the filter medium to the face piece is also disclosed. The process comprises depositing a first thin layer of solids from an aqueous slurry onto a foraminous suction mold having the surface contours desired for the interior of the filter medium, placing a face piece having an integrally formed apertured lip over the mold and the first layer, depositing a second thin fibrous layer of solids from an aqueous slurry on the outside surface of the first layer, on the outside surface of the apertured lip and within the apertures in the lip. In a preferred process, two fibrous backing layers are provided in this manner and a fibrous filter layer is deposited from an aqueous slurry on the outside surface of the second fibrous backing layer and within an undercut area provided in the apertured lip. An additional fibrous protecting layer is preferably deposited on the outside surface of the filter layer from an aqueous slurry.

7 Claims, 5 Drawing Figures



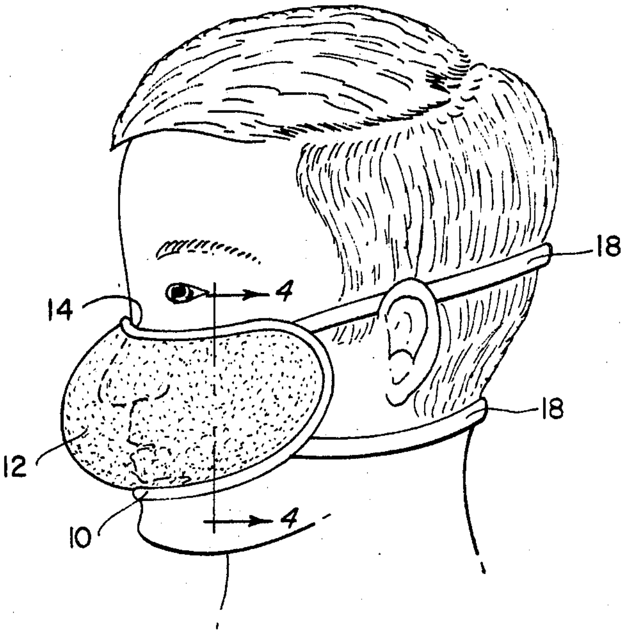


FIG. 1

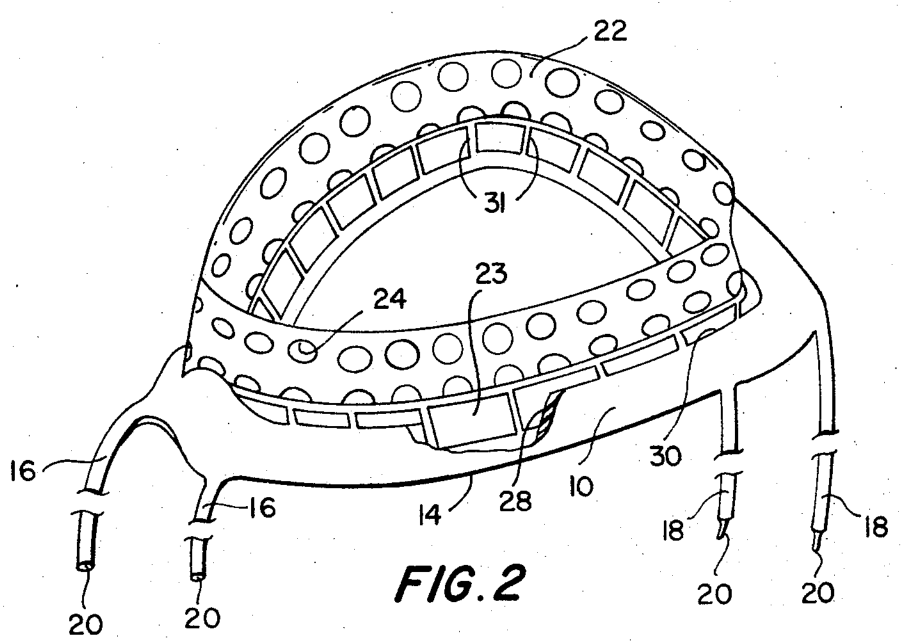


FIG. 2

INVENTORS
GEORGE P. REIMSCHUSSEL
JACOB M. PRINS

John A. McKinney
ATTORNEY

FIG. 3

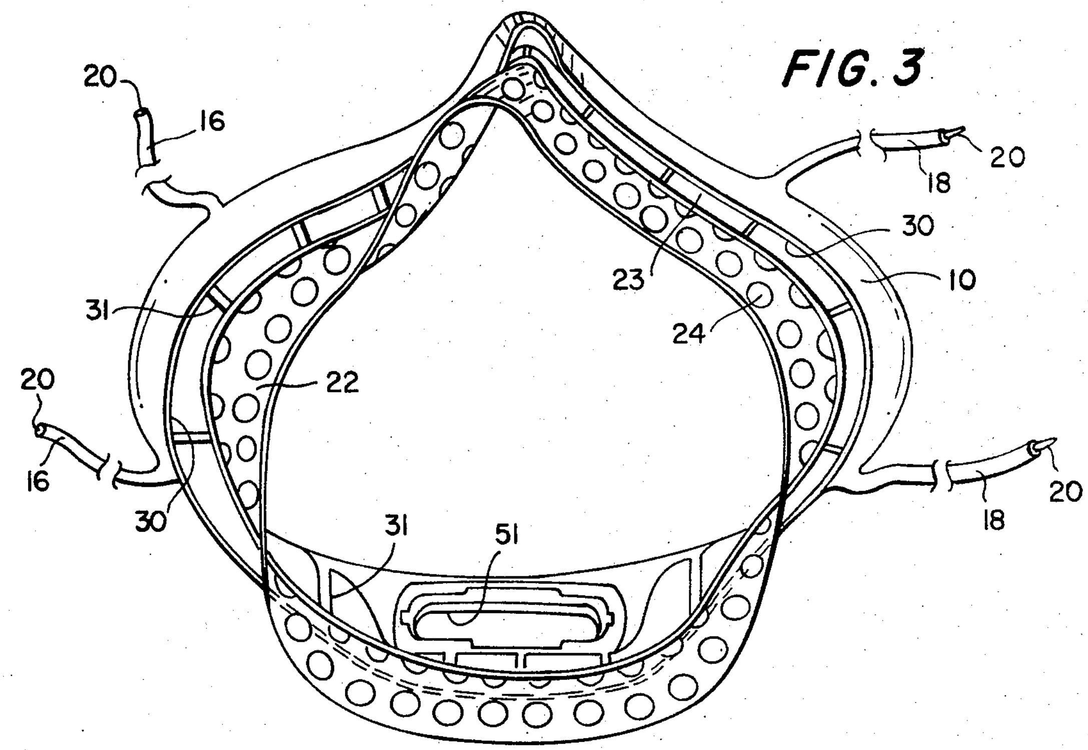


FIG. 4

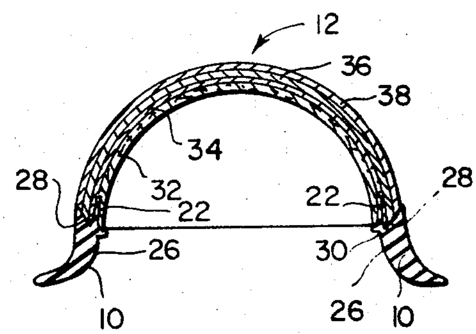
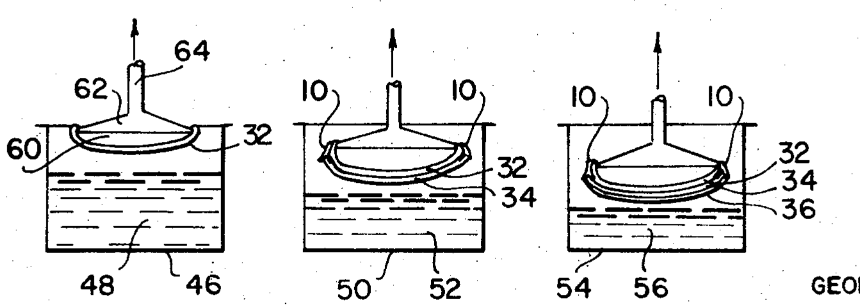


FIG. 5



INVENTORS
GEORGE P. REIMSCHUSSEL
JACOB M. PRINS

John A. McKinney
ATTORNEY

are preferred. Also, the amount of the pressure differential applied across the forming mold is a factor in determining the speed of the molding operation and has some effect on the characteristics of the deposited fibrous layers. Generally, for dilute slurries the pressure differential across the mold for depositing the first fibrous layer is from about 1 to about 10 inches of mercury. The pressure differential is usually increased for each succeeding layer, since the deposited layers act as a filter cake. As the thickness of the deposited solids increases, the filtration rate is slowed. It should be understood that the desired pressure differential across the mold depends on several factors including the porosity of the mold, and the porosity of the first formed layers, and the nature of the slurry. Thus, under some circumstances, it may be desirable to use pressure drops above or below the above-cited range.

For a clearer understanding of the mask construction and the methods of making the mask, specific examples are set forth below. These examples are illustrative, and are not to be understood as limiting the scope and underlying principles of the invention in any way. All percentages listed in the specification and claims are weight percentages unless otherwise noted.

EXAMPLE 1

A flexible face piece having an apertured lip is formed of a thermoplastic elastomer, sold by Shell Chemical Company under the trade designation "-KRATON," by injection molding. The face piece has the configuration illustrated in FIG. 2. The filter medium for the respirator mask is vacuum-formed on a porous firebrick mold. The mold is shaped to the desired form, and a rubber diaphragm is cemented to the back of the mold to allow application of a vacuum. The filter medium is formed by initially dipping the mold under a vacuum of about 1 inch of mercury into a first backing layer slurry and drawing the solids to the mold to form the first backing layer. The integrally formed face piece and apertured lip are then placed over the mold and the mold is then dipped into a second backing layer slurry to form the second backing layer. Subsequently, the mold is dipped into a filter layer slurry, and the mold is finally dipped into a protective layer slurry, to form, respectively, the filter layer and the protective layer. Thereafter, the vacuum is released and the filter medium and the face piece are blown off of the mold by positive air pressure.

The slurry used to form the first and second backing layers and the protective layer contains fine denier, high tenacity rayon fibers and binder. The slurry used to form the filter layer contains fine glass fibers, high tenacity rayon fibers and some binder. The aqueous slurries used to form each of the layers are prepared in 5-gallon quantities. Each respirator mask is formed by depositing 1.25 gallons of each slurry on the mold.

The slurry compositions used in forming the respirator mask are shown below:

	Slurry for Backing Layers & Protective Layer	Slurry for Filter Layer
1/8 – 1/2 in. lengths of random-cut high tenacity rayon fibers (a product of Celanese sold under the trademark "FORTISAN") having diameters of about 10 microns	6.00 gm	6.00 gm
1.6 – 2.6 micron diameter glass fiber (a product of Johns-Manville Corp. sold under the trademark "MICRO-FIBER")	—	3.51 gm
0.5 – 0.75 micron diameter glass fiber (a product of Johns-Manville Corp. sold under the trademark "MICRO-FIBER")	—	1.27 gm
Acrylic resin binder (50% solids by weight) (a product of B. F. Goodrich Chemical Co. sold under the trademark "HYCAR" #2600 × 120)	10 ml	3 ml
1 M NaOH	200 ml	100 ml
Water	Sufficient to give 5 gallons of slurry	

The fiber constituents are added to the slurries from concentrated stock suspensions having the following concentrations:

"FORTISAN" rayon fibers	1.5 gm/650 ml
1.6 – 2.6 micron "MICRO-FIBER" glass fiber	0.4 gm/100 ml
0.5 – 0.75 micron "MICRO-FIBER" glass fiber	0.25 gm/100 ml

The stock "FORTISAN" suspension is made by mixing the fiber and water for one minute in a Waring Blender. The stock "MICRO-FIBER" suspensions are made by mixing for 30 seconds in a Waring Blender and then bringing the suspension to pH 3 with 0.1 N HCl to achieve efficient dispersion.

After blowing the filter medium and the face piece off the mold, the filter medium is dried at 100°C. for about 1 hour to cure the binder.

When tested, the resulting respirator mask permitted only a very low percentage of dust to pass through the mask.

EXAMPLE 2

The filter medium is formed on a porous wire screen mold. The surface of the mold has the configuration of the desired interior surface of the mask and the filter medium is formed by the layered deposition of two different aqueous slurries using apparatus similar to that shown in FIG. 5. The working slurry used for forming the backing layers includes 0.16 grams per liter of acrylic fibers sold under the trademark "CRESLAN" by American Cyanamid and designated Type 61. These fibers are 1.5 denier and are nominally three-eighths inch in length. About 0.13 grams per liter of solids from an acrylic latex emulsion ("HYCAR" No. 2600 × 137) is deposited on the fiber. The backing layers working slurry also contains a small amount of wetting agent. Sodium hydroxide is added to break the latex emulsion and to deposit the latex on the fiber. Subsequently, the slurry is diluted to the working consistency described above.

For the filter layer, a working slurry is formulated which contains 0.159 grams per liter of acrylic fiber ("-CRESLAN" Type 61) and 0.041 grams per liter of "-MICRO-FIBER" glass fibers having a diameter of from 0.5 to 0.75 microns.

The respirator mask is formed by first integrally forming a flexible face piece made of polyvinyl chloride and including an apertured screen lip by a conventional injection molding process. A first backing layer containing about 0.375 grams of fiber and 0.312 grams of binder is deposited on the mold by drawing up 2.37 liters of the backing layers working slurry. A vacuum of about one inch of mercury is applied across the mold to draw up the slurry. The integrally formed face piece and apertured lip are then placed over the mold and over the first backing layer with the inside surface of the lip in contact with the first backing layer. A second backing layer is then deposited on the exterior surface of the first backing layer and on the exterior surface of the apertured lip by drawing an identical amount of slurry through the mold under a vacuum of about 2 inches of mercury. Subsequently, a filter layer is deposited on the mold and on the outer surface of the second backing layer by withdrawing 4.75 liters of the filter layer working slurry containing fine glass fibers under a vacuum of about 6 inches of mercury. An outer protective layer is then deposited on the outer surface of the filter layer by withdrawing from the backing layer working slurry 4.75 liters of slurry under a vacuum of about ten inches of mercury. The filter medium and the face piece are then blown off the mold by positive air pressure and held at about 100°C. for about 1 hour to cure the binder.

The present invention provides a uniquely constructed respirator mask and a unique process for manufacturing the mask. The filter medium is simultaneously formed and secured to a face piece. An apertured screen lip on the face piece ensures the secure fastening of the filter medium to the face piece and at the same time eliminates the extra step heretofore required in previous manufacturing processes of separately forming and fastening the filter medium to the face piece of the respirator mask.

It is to be understood that variations and modifications of the present invention may be made without departing from the spirit of the invention. It is also to be understood that the scope of the invention is not to be interpreted as limited to the specific embodiment disclosed herein, but only in accordance with the appended claims when read in the light of the foregoing disclosure.

What is claimed:

1. In a respirator mask including a shape retaining filter medium formed of a plurality of fibrous layers that cover a major portion of the surface area of the mask, and a flexible face piece attached to the periphery of said filter medium, said face piece having a face-sealing band at its outer periphery, said band being conformable to the contours of a wearer's face for preventing the passage of air between the face piece and the wearer's face, the improvement comprising a filter medium to face piece sealing joint that extends around the periphery of the filter medium, said joint comprising an apertured lip integral with and extending around the internal periphery of the face piece; a first fibrous backing layer of resin-bonded, interfelted resilient fibers, said layer contacting the inside surface of said apertured lip in a laminar relationship; and a second fibrous layer comprising interfelted fibers, the inner surface of said second layer at its peripheral portions contacting the outer surface of said apertured lip in a laminar relationship, and said inner surface of said second layer at its remaining portions overlying the outer surface of said first backing layer, fibers in said second layer extending into the apertures in said lip and contacting fibers in said first layer to hold said apertured lip in interlocking relationship between said first and second layers.

2. The respirator mask of claim **1** wherein said second fibrous layer is a backing layer comprising resin-bonded interfelted resilient fibers and wherein the filter medium includes a fibrous filter layer overlying the outer surface of said second backing layer.

3. The respirator mask of claim **2** wherein said apertured lip intersects the face-sealing band at an acute angle along a line spaced from the inner periphery of said band to provide an undercut area, said filter layer extending into said undercut area to provide an effective seal between the filter medium and the face piece.

4. The respirator mask of claim **3** in which said apertured lip includes circular openings spaced from said sealing band and quadrilateral openings adjacent said sealing band.

5. The respirator mask of claim **4** in which said circular openings are at least three-eighths inch in diameter.

6. A respirator mask as in claim **2** in which the filter medium includes:

a protective layer comprising bonded interfelted resilient fibers, said protective layer contacting the outer surface of said filter layer in overlying relationship, with said filter layer positioned between said second backing layer and said protective layer.

7. A respirator mask as in claim **2** wherein said fibrous filter layer includes fine diameter fibers.

* * * * *

peripheral portions of second backing layer 34 contact the outer surface of apertured lip 22 and fibers in second backing layer 34 extend through apertures 24 to contact fibers in first backing layer 32. The remaining portions of second backing layer 34 overlie and contact the outer surface of first backing layer 32. Layers 32 and 34 securely interlock the apertured screen lip in laminar relationship between them.

The fibers of the backing layers are selected to be coarse enough so that when interfelted by a vacuum molding process they form a fibrous layer containing pores that are too large to become plugged by the amount of binder necessary for adequate strength. Because the backing layers help provide the needed strength, resiliency, and abrasion resistance, no binder or a much smaller amount of binder can then be used in the filter layer. Thus, binder plugging of the filter layer is avoided without interfering with the filtration efficiency of the over-all filter medium.

Backing layers 32 and 34 are each preferably formed of short length (one-eighth inch or less up to about one-half to three-fourths inch), strong, stiff, and resilient fibers having a resilient water-insoluble binder distributed over the fibers. Fibers of about one-eighth inch or more in length tend to produce desirable surface corrugations which increase the effective surface area for filtration. Fibers in the backing layers can be of either random or graded lengths. As shown in FIG. 4, filter medium 12 includes a fibrous filter layer 36 in overlying contact with the outer surface of second backing layer 34. Filter medium 12 can further include a fibrous protective layer 38 which is similar to the first and second backing layers and which is comprised of bonded interfelted resilient fibers. Protective layer 38 overlies and contacts the other surface of filter layer 36.

The compositions of the backing layers, filter layer, and the protective layer can be those described in the aforementioned Weeks et al application. The disclosure of that application is incorporated herein by reference. BAcking layers 32 and 34 and protective layer 38 of this invention are each preferably composed of materials described as capable of being used in the backing layers of the above-identified application, while the composition of filter layer 36 is preferably the same as that for the filter layer discussed in said application.

For example, backing layers 32 and 34 and protective layer 38 can be formed of such suitable fibers as rayon, and various synthetic fibers such as acrylics, polypropylene, polyethylene, polyesters and polyamides. Preferably these fibers are of a denier of from less than 1 to about 1.5. Filter layer 36 preferably includes fine diameter fibers and strong, resilient fibers of a larger diameter. If desired, all the fibers in the filter layer can be fine diameter fibers. The fine diameter fibers can be selected from a variety of materials including glass and synthetic organic polymers which can be formed into fibers having desirable properties, such as stiffness, similar to those of glass fibers. These fibers can include polyvinyl chloride, polyamides and polypropylene. Glass fibers are, however, presently preferred. The larger diameter strong, resilient fibers can be selected from those described above for incorporation into the backing and protective layers.

The fibers of the filter layer tend to form a compact interfelted layer having small pores or interstices extending downwardly across the thickness of the layer and distributed throughout the surface area of the filter layer when drawn from a dilute aqueous slurry onto a foraminous mold. The strong resilient fibers are included in filter layer 36 to provide the necessary strength and resiliency and to act as a spacing means to prevent overcompaction of the finer fibers. In one preferred embodiment, the filter layer includes from about 4 percent to about 20 percent by weight of the fine fibers. It should be understood that the smaller the average diameter of the finer fibers used, the smaller is the weight percent of these fibers that is necessary to obtain good filtration efficiency. Also, when fine fibers having larger average diameters are used, larger amounts of the fine fibers can be present without causing excess breathing resistance. For example, when the fine fibers have diameters approaching about 1.6 microns, these fibers can be present in an amount over 20 percent. When fine fibers of larger average diameters, for example, about 1.6–2.6 microns, and above, are employed, these fibers can constitute 100 percent of the fibrous portion of the filter layer.

As illustrated in FIG. 3, the respirator mask can include an exhalation valve (not shown) which is fitted into aperture 51, although the filter medium itself usually permits comfortable exhalation. Suitable exhalation valves are commercially available; for example, inexpensive flapper valves can be used.

The invention also provides an improved process of forming a respirator mask. The process eliminates an intermediate step required in presently known manufacturing procedures for forming respirator masks including a face piece and a filter element by simultaneously forming the filter medium and securing the filter medium to the face piece of the mask.

In accordance with the process of this invention, a flexible face piece having a marginal face-engaging outer peripheral band and an inner peripheral portion that comprises an apertured screen lip is provided. A first thin fibrous backing layer of solids is deposited on a foraminous suction mold having the surface contour desired for the interior of the filter medium by drawing an aqueous slurry comprising resilient fibers and a binder material to the foraminous mold and passing water from the slurry through the mold. Then, the face piece and the apertured screen lip are placed over the foraminous suction mold and a second thin fibrous backing layer of solids is deposited on the outside surface of the first backing layer and on the outside surface of the screen lip in the same manner by drawing an aqueous slurry comprising resilient fibers and a binder material to the foraminous mold. FIG. 4 illustrates the relationship of first backing layer 32, face piece 10, and second backing layer 34. Water from the slurry is passed through the first backing layer, the apertures in the screen lip and the foraminous mold to sandwich the lip 22 between the first and second backing layers.

Subsequently, a filter layer of solids is deposited on the second backing layer from an aqueous slurry by drawing the slurry to the foraminous mold and passing water from the slurry through the first and second backing layers and the foraminous mold. Preferably, a protective layer is subsequently deposited on the filter layer. The protective layer is comprised of resilient fibers and a binder material as in the first and second backing layers. Deposition of the protective layer is also accomplished by drawing an aqueous slurry comprising resilient fibers and a binder material to the foraminous mold and passing water from the slurry through the first and second backing layers, the filter layer and the foraminous mold.

As shown in FIG. 5, a plural dip vacuum forming technique is preferably used in the manufacture of the respirator mask filter medium and in the attachment of the filter medium to the face piece. Although positive pressure could be applied to the aqueous slurry to create the pressure drop across the mold, a vacuum forming technique is preferred as described below.

In FIG. 5, the vacuum forming technique utilizes a tank 46 which contains a first fibrous slurry 48, a second tank 50 which contains fibrous slurry 52 having the same composition as that of slurry 48 and a third tank 54 that contains a third fibrous slurry 56 having a different composition from that of slurries 48 and 52. Although separate tanks 46 and 50 are illustrated, it should be understood that a single tank having the composition of slurries 48 and 52 therein could also be used. A foraminous mold 60 is attached to an airtight carrier 62 to which a conduit 64 is connected. The conduit connects the interior space between mold 60 and carrier 62 to a source of vacuum which is applied through the conduit to the interior surface of the mold when the mold is immersed in the fibrous slurry 48. The vacuum causes passage of the liquid in the slurry through mold 60 and the deposition of solids from the slurry 48 on the mold. It is this deposition of solids on the mold that forms first fibrous backing layer 32 for the mask.

After a layer of solids of a desired thickness has been deposited to form first backing layer 32, face piece 10 is placed over the mold with continuous surface 26 located adjacent to the mold and with the interior surface of lip 22 in contact with backing layer 32. Mold 60 is then inserted into fibrous slurry 52 in tank 50 while maintaining the interior of the mold and carrier structure under suction. Alternatively, mold 60 may be reinserted into slurry 48 when slurry 48 is identical in composition to slurry 52. Another vacuum forming operation is then carried out in tank 50 to provide second fibrous backing layer 34. This layer is formed over the first backing layer 32 and is formed on the outside surface of apertured screen lip 22. It is during this step and the succeeding steps of the process that the undercut area between apertured lip 22 and second surface 28 is important. Deposition of the second backing layer is accomplished by drawing an aqueous slurry 52 comprising resilient fibers and a binder material to the foraminous mold 60 and passing water from the slurry through first backing layer 32, the apertures 24 in screen lip 22 and the foraminous mold to sandwich the screen lip between first and second backing layers 32 and 34. The peripheral areas of second backing layer adhere to the outside surface of lip 22 and to first backing layer 32 through apertures 24 to produce a strong interlocking and laminar configuration. As a result, the filter medium is formed and simultaneously attached to the lip 22 of face piece 10. As the solids are being deposited on the outside surface of apertured screen lip 22, the space between the lip and second surface 28 enables the solid materials or fibers to be drawn into the space to effect a good seal between face piece 10 and apertured screen lip 22. Thus, the undercut area enables the solid materials to collect within the space to form the seal desired. If desired, a bead of cement (not shown) may be applied within the space or a heat-seal technique may be used to further insure retention of a good face piece to filter medium seal. The remaining portions of second backing layer 34 adhere to the outer surface of first backing layer 32.

Following the deposition of second backing layer 34, conduit 64, carrier 62 and mold 60 are removed from tank 50 and mold 60 is inserted into fibrous slurry 56 in tank 54 while maintaining the interior of the mold and carrier under suction. Another vacuum forming operation is then carried out in tank 54 which comprises fine diameter fibers to provide filter layer 36 which is formed over second backing layer 34. The filter layer is deposited by drawing slurry 56 to the foraminous mold 60 and by passing water from the slurry through the first and second backing layers and the foraminous mold. Again, the undercut area between surface 28 and apertured screen lip 22 permits solid materials to be deposited therein. The deposition of solids in this area provides a good seal between face piece 10 and apertured screen lip 22.

Preferably, a protective layer 38 is deposited on filter layer 36. This is accomplished by moving conduit 64, carrier 62 and mold 60 back to tank 50 and immersing the mold into slurry 52 for another vacuum deposition step. The mold is then removed from tank 50 and the filter medium is preferably cured at an elevated temperature to set the binder either while on the mold or after removal therefrom. The filter medium can be cured while on the mold by maintaining the vacuum and inserting the mold covered with the face piece and the fibrous layers into a hot air chamber, such as a drying oven. The hot air is drawn through the fibrous layers and the foraminous mold thereby permitting rapid setting of the binder material. Very short cure times of, for example, about 10 to 30 seconds can be achieved. If it is desired to cure the filter medium after removal from the mold, subsequent to removal from tank 50, the vacuum is discontinued and positive air pressure is applied to the conduit to remove the face piece and the fibrous layers formed on the outer surface of the mold. The filter medium is then heat cured.

It should be understood that in most cases fibers from a layer being deposited extend somewhat into the pores or interstices of a previously deposited layer, with the layer being deposited overlying the previously deposited layer.

The exterior surface of foraminous mold 60 is shaped to have the dimensions of the desired interior surface of the filter medium. The mold can be made from any suitable porous material such as, for example, highly porous ceramic material such as firebrick, or a fine mesh screen.

As set forth in the aforementioned Weeks et al application, it is desirable that the aqueous slurries be very dilute to ensure that the solids in the slurries remain uniformly distributed throughout. Solids concentrations of from about 0.015 percent to about 0.03 percent by weight based on the total weight of the slurry

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