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Pandemic Face Mask

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PANDEMIC FACE MASK

Open Source Technical Disclosure

Current respirator masks, such as the 3M 7500 series mask, are designed to protect the wearer and are extremely effective at filtering out incoming particles and droplets.

However, the current coronavirus pandemic requires masks that protect both the wearer and the general public, and therefore the masks need also to filter outgoing particles and droplets.

It is an object of this invention to construct a face mask that will:

1) Provide an inlet filter to remove 99.97%[1] of viruses from inhaled air
2) Provide an outlet filter to remove 99% of viruses from exhaled air
3) Prolong the life of the inlet filter with a valve that blocks exhaled air and exhaled droplets from entering the inlet filter
4) Prolong the life of the outlet filter through a two-stage design, wherein
    a. The first stage includes an inertial separator to separate larger droplets, wherein:
        i. The inertial separator includes tortuous passages or baffles that force the outgoing airflow to abruptly change directions, or,
        ii. The inertial separator includes a cyclonic separator.
    b. The first stage having a trap to collect and pool liquid water from the collected droplets
5) Have the second stage comprising a flexible tube in which:
    a. One end of the tube is attachable to the mask outlet and is attachable to existing masks to retrofit for the current pandemic
    b. The other end of the tube can be tucked into the wearer's shirt or other clothing
    c. The tube can flex to accommodate movements of the neck
    d. The tube can expand to accommodate each tidal volume of an exhalation, thereby "flattening the curve" of the cyclic breathing by reducing the peak flow out of the tube and through the clothing, thereby enabling a more consistent, lower velocity flow through the wearer's clothing, increasing filtering efficiency.
    e. The exhaled air, with its moisture, is directed by the tube away from the face so that the moisture does not contaminate and prematurely destroy the inlet filter and does not fog the wearer's glasses.
6) Have the second stage empty into a HEPA filter bag, which functions both as a filter and an accumulator to also "flatten" the exhalation curve.

The lower (99%) estimated effectiveness of the outer filter is acceptable because:

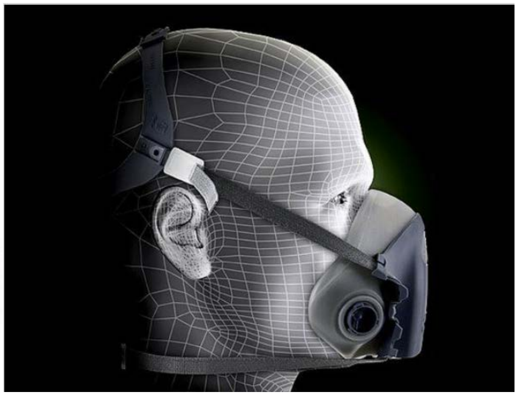
1) It is at least as effective as other masks commonly available
2) The 99.97% inlet effectiveness protects the wearer from infection, reducing the probability of viruses even being present in the wearer's exhaled air
3) The 99.97% inlet effectiveness increases compliance with mask-wearing rules by motivating the wearer through appeal to his self-interest.

[1] Standard P100 and HEPA Filters filter out 99.97% of incoming particles of diameter 0.3 microns or higher.

EXAMPLE: 3M 7500 MASK

The 3M 7500 mask is used in toxic industrial environments, such as encountered in asbestos removal and spray painting. The mask accommodates a pair of replaceable inlet filter cartridges, one on each side of the face. Inhaled air is drawn through these filters then through one-way inlet valves. During exhalation, these inlet valves close, and an outlet valve opens, directing exhaled air through a duct centered in the mask and pointed downward.

The mask incorporates an elastomeric seal made of silicone that accommodates and seals with the contours of the wearer's face.



More detail available at 3M.com or at:

https://pksafety.com/3m-7500-series-half-facepiece-respirator/

CUSTOMIZED PROTOTYPE BASED ON 3M 7500 MASK

Mask with pair of P100 Filters

Mask outlet surrounded by Velcro tape

Mask with a flexible tube (woven sleeve) secured to mask outlet by Velcro tape

TESTING OF PROTOTYPE

The usability limits of this prototype were tested by wearing the mask while cycling for approximately 8 hours. The level of exertion was between 100 and 300 watts, as measured through the bike's power meter. Sustained exertion up to a level of 200 watts was possible without noticeable resistance to inhaling. The large surface area of the pair of 3M P100 filters gives it a very high flow capacity. However, sustained riding at an exertion level over 200 watts resulted in noticeably labored inhalation.

Approximately 1cc/hour of liquid water pooled in the bottom of the elastomeric bottom of the mask, providing evidence of the inertial separation and pooling of droplets.

CONCLUSION

The tests demonstrate that a mask that is long-lasting, as well as highly protective of both the wearer and society, can be worn for very demanding activities.

The prototype pictured above was trivial to construct simply by sticking velcro onto an existing 3M 7500 mask. Any mask with an outlet valve can be similarly adapted simply by sticking velcro around the valve's perimeter.

In the current environment of severe PPE shortages, necessitating a Do-It-Yourself (DIY) pandemic response, this may be an optimal, swift, and practical adaptation for mitigating risks to health and safety.

Such a DIY solution may also eliminate the need for well-intentioned, yet misconceived laws, such as that passed in San Francisco, that ban wearing any mask with an outlet valve due to concerns of potentially hazardous exhalation. In fact, any mask without such a valve is almost certainly ineffectual at incoming and outgoing filtration or will quickly be made so by the moisture from a day's exhalation (as an aside, laws such as these should be modified with the qualifier "*... that exhausts unfiltered air.*")

ALTERNATE PROTOTYPE WITH HEPA FILTER

To filter 99.97% of the exhaled 0.3-micron droplets, the DIYer can attach a (nonporous) exhale tube to a HEPA vacuum bag (see photo to the right).

HEPA vacuum bags are inexpensive and readily available for sale (as of May 8, 2020). They have a very high flow capacity and capacity to absorb moisture. The HEPA bag can be placed in a backpack or inside the shirt or jacket of the wearer.

APPENDIX: CALCULATION OF THE (APPROXIMATE) 99% FILTERING EFFECTIVENESS

The calculation below estimates the effectiveness of using the wearer's clothing to filter his exhaled air. For example, if the wearer tucks the mask outlet tube under his jacket, it estimates how the jacket material can filter droplets from the air passing through it. The settling speed of the droplets is first calculated to estimate whether droplets will settle and stick to the jacket material.

Droplets 30 microns or less in diameter settle in air according to the Stokes equations for viscous fluid flow. The Stokes equations applied to water droplets in air result in the following formula for the settling velocity: $V = 30 * D^2$, where V is in microns/second, and D is droplet diameter in microns. For a 0.3 micron droplet, the settling velocity is approximately 2.5 microns/sec.

A typical exhaled tidal volume of 500 ml, spread out over a typical 4-second breath cycle yields a flow rate of 125 ml/sec. The tube, tucked into the wearer's shirt, distributes this flow evenly through a shirt of area 0.5 $meters^2$, resulting in an outward velocity of 0.25 mm/sec. Assuming a cloth thickness of 2 mm yields a residence time of 8 seconds. A 0.3 micron droplet, which settles at a speed of 2.5 microns per second, would fall 20 microns in that residence time. In contrast, a 3.0 micron droplet would fall much faster: 2,000 microns in that time.

Athletic apparel is typically made from cotton or lycra with pore sizes typically in the range of 10-100 microns. My guess is that these fabrics would capture most of the droplets. Those skilled in the art of filtration materials may give a better guess or identify more optimal fabrics.

Alternately, the HEPA filter described above filters the full 99.97% of the 0.3-micron droplets.

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