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Advanced Manufacturing Center_Comparative Protective Mask Material Testing

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Comparative Protective Mask Material Testing

Disclaimer
It is not testing to the ASTM standard used to qualify N95 Masks
It is not an analysis approved by the FDA
It is not a test of biological effectiveness of preventing/filtering VIRUSES or any version of COVID-19.
It is not a test of biological activity or the ability of a VIRUS or COVID-19 to live on the surface

These tests were on a limited number of samples of each mask tested. It is not a test on the quality control of the manufacturing process.

Theory
There are many different types of materials used in protective masks used as protection from everything from nuisance dust to viruses. The Advanced Manufacturing Center saw a need to be able to objectively look at material and make a determination on how effective it can be at stopping particles. The AMC developed a comparative test employing a standard TSI 8038 PortaCount Pro+ respirator fit testing machine. This machine has the ability to measure a materials particle filtering effectiveness as it is being drawn through the material.
Appendix A shows the machine manual on its theory of operation and specifications on minimum size particle it can detect. Literature states a particle detection down to 0.015 Micron.

Test Setup
The PortaCount was fitted with a test chamber that could seal material with a worm drive clamp or threaded band. See Figure 1, 2, 3

Figure 1: Chamber Opening

Figure 2: Chamber Base hose port sealed with an o-ring

Figure 3: Test material sealed to chamber

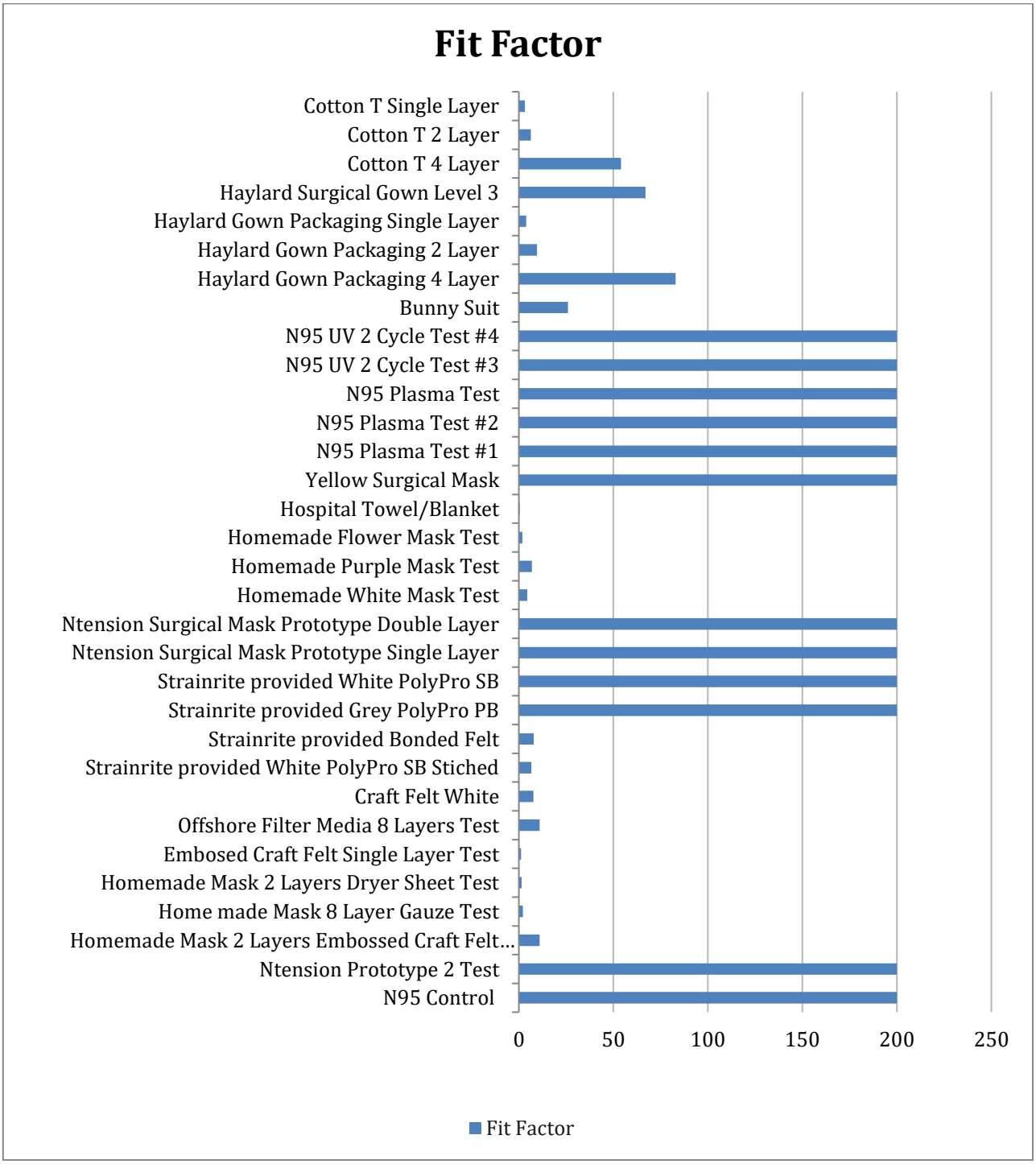
Testing process
Before each testing session the PortaCount is calibrated using the standard procedure outlined in the manual. Before testing new materials an N95 mask is tested to check base line and for any potential leaks in the apparatus. See figure 4. The PortaCount is run in Real Time mode with N95 Enabled. The reading needs to be 200+ on the fit factor for the N95 respirator.

Figure 4: N95 Respirator results

Once base line is verified, other materials can be tested to see if they have the ability to filter as many particles as an N95 respirator and achieve a fit factor of 200+.

Figure 5: Homemade mask results

Material Test Results as of 3/31/2020



All machine info can be found at the TSI website, Portacount Pro+ 8038 manual found here.

https://www.tsi.com/getmedia/76df3dbb-6d8d-4d78-aa24-5aff19e889e9/8030_8038_PortaCountPro_Manual_6001868?ext=.pdf

Appendix A:

Specifications

(Specifications are subject to change.)
Model 8030 PortaCount Pro Respirator Fit Tester
Size ..... 9.5 x 8.5 x 6.75 in.
(24 x 22 x 17 cm)
Weight
Unit only..... 5.0 lb. (2.7 kg)
With standard accessories and case... 16 lb. (7.3 kg)
Fit Factor Range ..... 1 to greater than 10,000
Concentration Range ..... 0.01 to 2.5 x 10^5 particles/cm^3
Particle Size Range ..... 0.02 to greater than
1 micrometer
Typical Fit Factor Accuracy..... ±10% of reading up to fit factors of 10,000
Temperature Range
Operation ..... 32 to 100°F (0 to 35°C)
Storage ..... -40 to 160°F (-40 to 70°C)
Flow Rate
Sample ..... 350 cm^3/min
Total..... 1000 cm^3/min (nominal)
Power Requirements..... 100 to 250 VAC, 50 to 60 Hz
Alcohol
Hours per charge ..... 6 hours at 70°F (21°C)
Alcohol type..... Reagent grade isopropyl
(99.5% or better)
Carrying Case
Size ..... 19.5 x 13.7 x 9 in.
(49.5 x 34.8 x 23 cm)
Pass/Fail Settings..... User-selectable: 0 to 10000
Factory Recalibration Interval ..... 1 year
Warranty..... Two years on workmanship
and materials

Respirator Face pieces that can be Fit Tested
Full-face elastomeric
Half-face elastomeric
NIOSH series-100 filtering-face piece
NIOSH series-99 filtering-face piece
NIOSH series-95 filtering-face piece (8038 upgrade required for Series-95 only)

Fit Factor Measurement
Direct measurement of fit factor (C_{out}/C_{in})
(Mask leakage is measured simultaneously while test subject moves and breathes.)

Model 8038 PortaCount Pro+ Respirator Fit Tester
Size ..... 9.5 x 8.5 x 6.75 in.
(24 x 22 x 17 cm)
Weight
Unit only..... 6.8 lb. (3.1 kg)
With standard accessories and case... 18 lb. (8.2 kg)
Fit Factor Range ..... 1 to greater than 10,000;
1 to 200 for < 99% efficiency masks
Concentration Range ..... 0.01 to 2.5 x 10^5 particles/cm^3

Particle Size Range ..... 0.02 to greater than 1 micrometer
Typical Fit Factor Accuracy..... ±10% of reading up to fit factors of 10,000
Temperature Range
Operation ..... 32 to 100°F (0 to 35°C)
Storage ..... -40 to 160°F (-40 to 70°C)

Flow Rate

Sample ..... 350 cm^3/min
Total..... 1000 cm^3/min (nominal)
Power Requirements..... Autosensing 100 to 250 VAC, 50 to 60 Hz
Alcohol
Hours per charge ..... 6 hours at 70°F (21°C)
Alcohol type..... Reagent grade isopropyl (99.5% or better)
Carrying Case
Size ..... 19.5 x 13.7 x 9 in. (49.5 x 34.8 x 23 cm)
Pass/Fail Settings..... User-selectable: 0 to 10000
Factory Recalibration Interval ..... 1 year
Warranty..... Two years on workmanship and materials

Respirator Facepieces that can be Fit Tested
Full-face elastomeric
Half-face elastomeric
NIOSH series-100 filtering-facepiece
NIOSH series-99 filtering-facepiece
NIOSH series-95 filtering-facepiece
Fit Factor Measurement
Direct measurement of fit factor (C_{out}/C_{in})
(Mask leakage is measured simultaneously while test subject moves and breathes.)

Appendix B

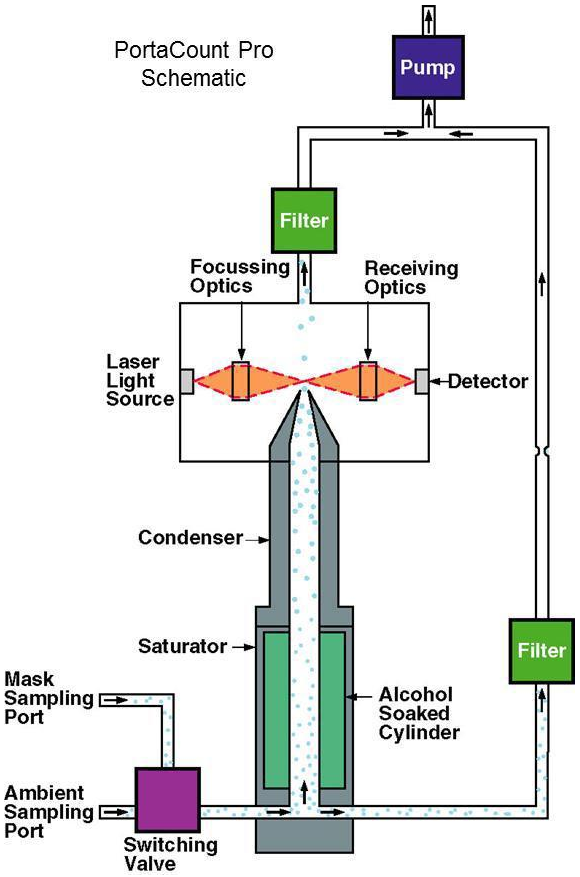
Theory of Operation

How the PortaCount Pro Respirator Fit Tester Works

The PortaCount® Pro fit tester measures respirator fit by comparing the concentration of microscopic particles outside the respirator to the concentration of particles that have leaked into the respirator. The ratio of these two concentrations is called a fit factor. A fit factor of 100 means that the air inside the respirator is 100 times as clean as the air outside.

$$\text{Fit Factor} = \frac{\text{Outside Concentration}}{\text{Inside Concentration}}$$

Since the microscopic particles in the air cannot pass through the class-100 or class-99 filters used on the respirator, any particles that get into the respirator must have come in through a leak. The PortaCount Pro fit tester has two sample tubes, one samples ambient air and the other attaches to the respirator and samples from inside it. A valve inside the PortaCount
Pro fit tester switches from one tube to the other according to a programmed sequence.



How the PortaCount Pro Fit Tester Counts Particles

The PortaCount Pro fit tester is based on a miniature, continuous-flow Condensation Nucleus Counter (CNC), also known as a Condensation Particle Counter (CPC). A CNC takes particles that are too small to be easily detected, grows them to a larger, easily detectable size, and then counts them.

The idea of CNCs/CPCs is not new. As early as 1888, Aitken described a dust counter that grew particles to detect them. In 1943 the Nolan-Pollack photoelectric CNC was described. In the 1950s and 1960s, commercial, automatic CNCs were available. However, none were of the continuous-flow type, and the PortaCount Respirator Fit Tester is the first highly portable continuous-flow CNC.

The concept of using a condensation nucleus counter (CNC) for the purpose of quantitative respirator fit testing was first demonstrated in 1981 by Dr. Klaus Willeke of the University of Cincinnati. Reference: Willeke, K., H.E. Ayer, J.D. Blanchard. “New Methods For Quantitative Respirator Fit Testing With Aerosols,” *American Industrial Hygiene Association Journal,* Feb. (1981).

The PortaCount Pro Respirator Fit Tester grows submicron particles to supermicron alcohol droplets and then measures the concentration of the alcohol droplets. This makes the PortaCount Pro Fit Tester sensitive to particles with diameters as small as 0.015 microns, but insensitive to variations in particle size, shape, composition, and refractive index. Thus, quantitative fit testing can be performed with virtually any aerosol, including ambient air. Aerosol is drawn through the instrument by a diaphragm vacuum pump operating at a flow rate of 1.0 liter per minute. The flow enters the instrument through either the ambient port or the sample port. The switching valve determines which port is used. The outlet of the switching valve leads to the saturator end cap, where the flow splits.

A flow rate of 0.35 liters per minute enters the saturator and passes through the condenser, nozzle, and sensing volume. The remaining flow passes through the excess airline and is recombined with the sampled flow down-stream of the sensing volume.

The PortaCount Pro sensor consists of a saturator, condenser, and optical elements. The saturator is lined with an alcohol-soaked wick. A thermoelectric device is mounted between the saturator and condenser which cools the condenser and heats the saturator. After passing through the saturator, the aerosol (now saturated with alcohol vapor) enters the condenser tube. The alcohol vapor condenses on the particles, causing them to grow into droplets. The droplets then pass through the nozzle and into the sensing volume as depicted in the schematic diagram below.

The focusing optics in the sensor consists of a laser diode and a series of lenses that focus the laser light into a sensing volume just above the nozzle. Each particle passing through the sensing volume scatters light. The light is collected by the receiving optics and focused onto a photodetector. The photodetector generates an electrical pulse from the scattered light as each droplet passes through the sensing volume. The particle count is determined by counting the number of pulses generated during a given time period. Knowing the particle count, time period and flow rate allows particle concentration to be computed.

Appendix C

Calculating Fit Factor
Fit factor is defined as the particle concentration outside the respirator divided by the particle concentration inside the respirator.
Because ambient concentration can vary over time, the PortaCount® Pro Respirator Fit Tester calculates the fit factor by taking the average of the ambient concentrations measured before and after the respirator sample and then dividing by the concentration measured in the respirator. This is why the first test cycle (exercise) is longer than additional test cycles in Fit Test Mode. It is necessary to measure the required additional ambient concentration sample before the first fit factor can be calculated. Both the ambient and respirator concentrations are determined by integration. The integrated concentrations are determined by the total number of particles counted during the sample periods.

Fit factor is actually calculated by:
where: FF = fit factor $= \frac{CB+CA}{2CR}$

CB = particle concentration in the ambient sample before the respirator sample
CA = particle concentration in the ambient sample after the respirator sample
CR = particle concentration in the respirator sample.

If no particles are counted in the respirator sample, the PortaCount
Pro fit tester automatically adds one particle. This prevents dividing the ambient concentration by zero. At the end of a fit test, the overall fit factor is calculated and displayed, based on the individual fit factors for each test cycle.