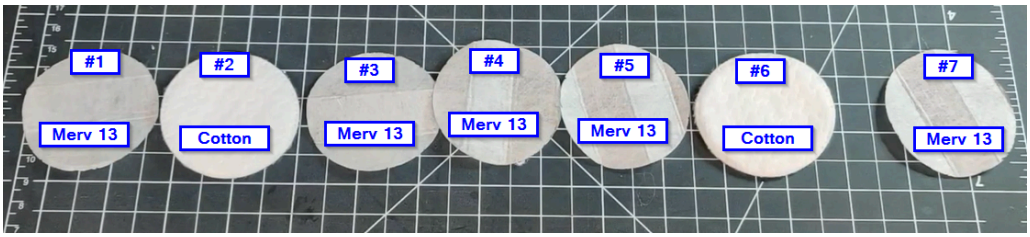
Filter Materials and Layering Research

By Joshua “MalaMaker” Malavolti

Project folder: https://drive.google.com/drive/folders/17v80mLmWdSHgmpojCnGb660X7t5SeWA5?usp=sharing
Project Page: https://wiki.rivercitylabs.space/covid-19/3d-printed-masks

Conclusion:

Proper Layering:

- 

Lab Results:

- Test 6:
  https://drive.google.com/open?id=1yupGFIhwD8AysjFTFQhwAgz6Ek0EjDfb
  - Average of 97.66% efficient over 5 samples at the 0.3 micron spec @ 84 liters/minute.
  - Average of 93.067% efficient over 3 samples at the 0.3 micron spec over 80 minutes @ 84 liters/minute.
    - 80 Minutes @ 84 liters/minute equates to roughly 16 hours of use by a typical human adult (11 liters/minute).
    - Based on the lab results, after roughly 20 minutes into the cycle the efficiency dropped below the 95% efficiency threshold. This equates to roughly 2.5 hours of use at 11 liters/minute before the filter media dropped below the 95% efficiency threshold. Suspect air speed is a contributor to the breakdown.
  - Efficiency Range of 92.5% - 98.1% over all 8 samples @ 84 liters/minute.
  - 5 of the 5 samples were at or above 95% for initial efficiency @ 84 liters/minute.
- Test 8:
  https://drive.google.com/file/d/1_RuipkcYF8WzaTJqf0Vsohv_ObHyBu_A/view?usp=sharing

        - Average of 99.9697% efficient over 3 samples at the 0.3 micron spec @ 32 liters/minute.
        - Average of 3.983mm/H2O of restriction @ 32 liters/minute.
        - Average of 99.9333% efficient over 3 samples at 2 data points each at the 0.3 micron spec @ 84 liters/minute.
        - Average of 10.25mm/H2O of restriction over 3 samples at 2 data points each @ 84 liters/minute.
    - Test 9: https://drive.google.com/file/d/1_RuipkcYF8WzaTJqf0Vsohv_ObHyBu_A/view?usp=sharing
        - Wearer got light headed wearing this one within 5 minutes
        - Average of 99.9697% efficient over 3 samples at the 0.3 micron spec @ 32 liters/minute.
        - Average of 6.433mm/H2O of restriction @ 32 liters/minute.
        - Average of 99.1433% efficient over 3 samples at 2 data points each at the 0.3 micron spec @ 84 liters/minute.
        - Average of 16.10mm/H2O of restriction over 3 samples at 2 data points each @ 84 liters/minute.

Final Assessment:

- N95 Level Category (Ref Visual guide produced by CrossTex: PDF):
    - Based on the data gathered and through consulting with the experts in both the mask and filter world. Also addressing breathability as to not suffocate the user and the efficiency of the filter at the 0.3 micron spec. The test that showed the most promise to cover both of these categories is “Test 8”. “Test 8” is comprised of five 3M Merv 13 filter material, rated at 62% efficent at 0.3-1.0 micron / 87% efficent at 1.0-3.0 / 95% efficent at 3.0-10, and two cotton layers measuring 0.6mm-0.85mm thick @ 1lb 9oz of pressure over a 3mm by 10mm area (Brand: Swisspers Regular Cotton Rounds or Warm and White Cotton Batting). The proper layering is: 1x merv 13 + 1x cotton + 3x merv 13 + 1x cotton + 1x merv. The cotton layers show important to the layering due to their buffering of the inner core (3 middle layers of Merv 13). It appears that the cotton also contributes to the breathability of the mask based on the density of the cotton over a specific area. In conclusion the “Test 8” sample is the combination that meets the efficiency spec and breathability balance in a sealed mask.
    - This is considered a “Maximum Filtration” alternative. If you are exposed to an aerosol environment, a "Maximum Filtration" mask and filter is appropriate. Typically people that are exposed to these conditions are going to be in emergent healthcare, ICU healthcare and first responders (Fire and EMT). For the majority of people who are not exposed to these

conditions, a "ASTM Level…[1-3]" mask / alternative would be appropriate.

Other Discoveries:

- Level 1 Category (Ref Visual guide produced by CrossTex: PDF):
  - Based on the data gathered and through consulting with the experts in both the mask and filter world. 2 Materials have been discovered with proper evidence to show they will filter at the Level 1 surgical mask category as defined in the “EN14683 Rating – Type II Standard” (Ref Visual guide produced by CrossTex: PDF). One material “AFI MBBFE95: Meltblown PP Face Mask Filtration Media” (See “Materials” section, “Level 1 Meltblown PP #1”) and supporting Lab results show this material to be a proper Level 1 material. The other material found to filter at a Level 1 filtration was the Merv 13 material found in the 3M filtrete 1900 furnace filter polypropylene baffle. This material when using 2 layers shows to filter at the BFE, PFE, and Delta P specs defined and meet the proper air flow requirements to classify it as a level 1. (See PDF)
- Level 2 Category (Ref Visual guide produced by CrossTex: PDF):
  - Based on the data gathered and through consulting with the experts in both the mask and filter world. 1 Material combination has been discovered with proper evidence to show it will filter at the Level 2 surgical mask category as defined in the “EN14683 Rating – Type II Standard” (Ref Visual guide produced by CrossTex: PDF). The material found to filter at a Level 2 filtration was the Merv 13 material found in the 3M filtrete 1900 furnace filter polypropylene baffle. This material when using 3 layers shows to filter at the BFE, PFE, and Delta P specs defined and meet the proper air flow requirements to classify it as a level 2. (See PDF)

Materials:

Honeycomb: 3mm Printed plastic PLA/PETG

Merv 16: Nanowave Synthetic Filter Media

- MSDS: [TODO: Need to pull MSDS]
- Product Sheet: https://www.hollingsworth-vose.com/Documents/Product%20Literature-Filtration/NanoWave%20Synthetic%20Filter%20Media.pdf
- Product Site: https://nanowave-hv.com/
- TSI 8130 Results: 90% efficient @ 0.3 microns with a 3.15 mm of H2O

Merv 12: 3M Filtrete 1500 pleated HEPA furnace filter (non-fiberglass)

- MSDS: [TODO: Need to pull MSDS]
- SKU: 051141399461
- Water does not flow through the material
- Sewable
- Washable Results: Survived 1 cycle of washer/dryer.
- Thickness: 0.39mm
- Filter material: polypropylene and polyolefin plastic
-

Merv 13: 3M Filtrete 1900 pleated HEPA furnace filter (non-fiberglass)

- MSDS: [TODO: Need to pull MSDS]
- SKU: 051111540961
- Water does not flow through the material
- Sewable
- Washable Results: Survived 1 cycle of washer/dryer. Multi Wash (5) no visible deterioration, photos to follow.
- Thickness: 0.49mm
- Filter material: polypropylene and polyolefin plastic
- Weight: 15x 57mm Diameter Circles = 0.1oz
- Parker Hannifin has done efficiency tests on surgical grade masks and has found them to range from 62%-84%. Merv 13 is showing to be a 62% efficiency based

on information provided on the packaging. Parker Hannifin has provided laying efficiency to achieve various levels of filtrations at 84 liters/minute

- Parker Hannifin Layering Results completed on TSI 8130 (PDF)

Layer Count	Efficiency	Restriction (mm/H2O)	ASTM Mask Level (PDF)
1	80.5%	1.7	
2	95.5%	3.1	Level 1
3	98.6%	4.5	Level 2

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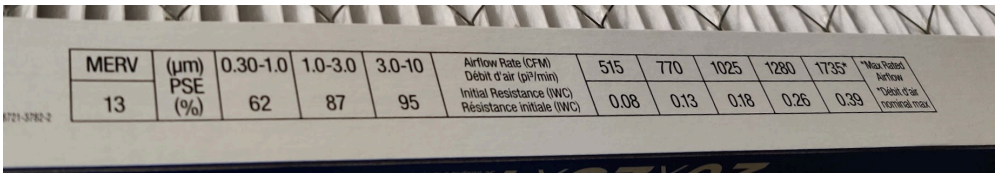

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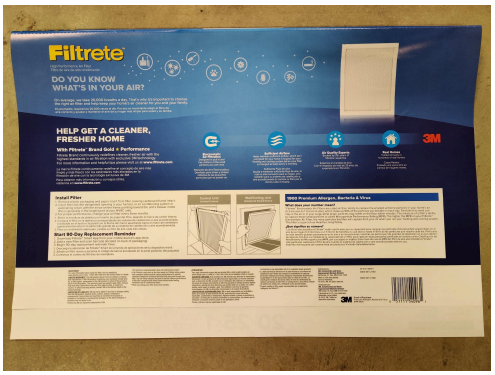


Level 1 Meltblown PP #1: Air Filters, Inc - AFI MBBFE: Meltblown PP Face Mask Filtration Media

- Material Information and Lab Results: https://drive.google.com/open?id=1VtV0DAG8FW4lJqr67GTefePfnY6JC46x
- Note: Lab results provided by Air Filters Inc in Houston, TX
- Note: BFE rating of 95%
    - Comment: Equates to a Level 1 surgical mask material. See PDF.

cotton round #1: Sky Organics Cotton Rounds

- MSDS: [TODO: Need to pull cotton MSDS]
- SKU: 856045007661
- Marked “All-Natural 100% Cotton”
- Notes: “Two Textured: Woven layer…”
- Smash thickness: 1.12mm @ 1lb 9oz of pressure over a 3mm by 10mm area

cotton round #2: Swisspers Regular Cotton Rounds

- MSDS: [TODO: Need to pull cotton MSDS]

- SKU: 048341007777
- Manufactured by US Cotton
- Marked “Made from 100% pure natural cotton”
- Notes: Cotton Brand Trademarked
- Smash thickness: 0.85mm @ 1lb 9oz of pressure over a 3mm by 10mm area

cotton round #3: Equate Beauty Premium Cotton Rounds

- MSDS: [TODO: Need to pull cotton MSDS]
- SKU: 681131164924
- Marked “Premium Cotton Rounds”
- Notes: “100% Pure Cotton” Cotton Brand Trademarked
- Smash thickness*: 1.26mm @ 1lb 9oz of pressure over a 3mm by 10mm area

cotton round #4: Equate Beauty Premium Woven Exfoliating Round

- MSDS: [TODO: Need to pull cotton MSDS]
- SKU: 681131248716
- Marked “Premium Woven Exfoliating Round”
- Notes: “Hypoallergenic Dual Textured:...”
- Notes: “100% Pure Cotton” Cotton Brand Trademarked
- Smash thickness: 1.45mm @ 1lb 9oz of pressure over a 3mm by 10mm area

cotton #5: Warm and White Cotton Batting

- MSDS: None
- Marked “Does Not Contain Resins or Glue”
- Notes: “87.5% Bleached Cotton, 12.5% Polypropylene”
- Notes: “Made by The Warm Company”
- Notes: “Federal RN # 132520”
- Notes: “Reg. No. PA-24653 (WA)”
- Manufacturer Part Number: 2531
- Smash thickness: 0.6mm @ 1lb 9oz of pressure over a 3mm by 10mm area

- Honeycomb

Research: Filter Materials and Layering
(For Reference Only when printed) https://docs.google.com/document/d/1PvpCbRq_Sh6PIX0ziEDmQvnjWnJY5d0YOeTuWkOZNnA/edit?usp=sharing

- PETG plastic
- Thickness: 3mm
- 2mm Square holes separated with 2mm divisions
- Wall gap spacing tolerance: 0mm - 0.3mm
- Notes: Acts as an air spreader and to maximize the whole filter usage. By using a honeycomb on entry and on exit this even maximizes the filter usage throughout the entire thickness of the filter. Also acts as an air disruptor when multiple layers are used so the air does not pass in a straight line.

Manufacturing:

Merv Material:

- Laser Cut: Yes but NOOOOO (It smells like camp fire through the filter)
  - Video Trial Cutting: https://photos.app.goo.gl/5Y3bBJTsiiA7ssgE6
- Punch Cutting: Kinda, A cheap one does not break through and leaves strings attached
  - https://www.americanbuttonmachines.com/collections/punch-cutter/products/2-25-photo-punch
- Circle Cutter: Yes
  - https://www.americanbuttonmachines.com/collections/adjustable-circle-cutter/products/circle-cutter
- Fabric CNC Cut: Yes
  - Jonco ($0.21/circle + material)
- Cricut Maker
  - Using a Rotary Blade
- Cricut Explore Air 2
  - Pending… Per Kurt Lippert from Austin, TX: “felt wool material, fine point blade. It does like 5+ passes per round and likely too many, going to fine tune number today”

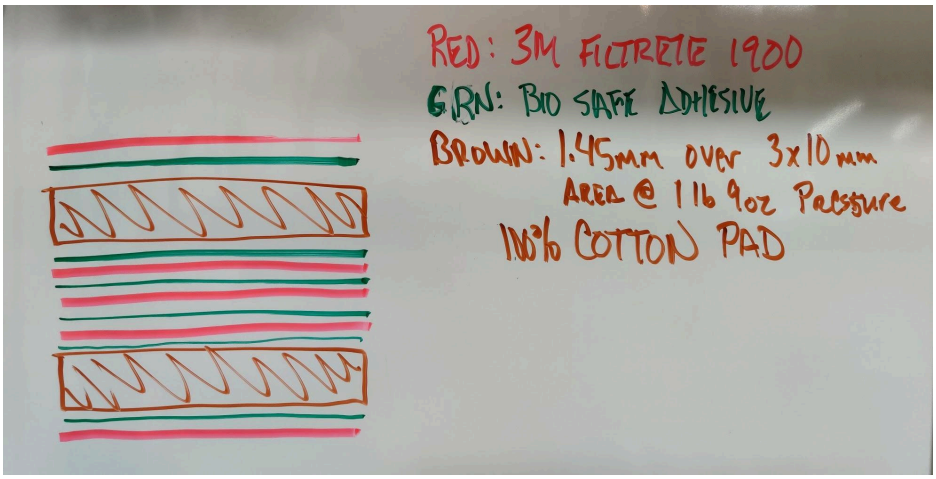
Cotton Rounds

- No manufacturing needed, redesigned filter model to accommodate the size. Cotton matting will need to be cut to size but users will need to make sure the density is correct. Density instructions will be listed in this document.

Filter Layer Adhesion

- Heat sealing
  - Top and bottom layers sealed together sandwiching the internal layers in as one cartridge.
    - Roll sealer
    - Stamp sealing
    - Bag sealer
- (Ideal) Bio Friendly Adhesion

Research: Filter Materials and Layering
(For Reference Only when printed) https://docs.google.com/document/d/1PvpCbRq_Sh6PIX0ziEDmQvnjWnJY5d0YOeTuWkOZNnA/edit?usp=sharing

- Essentially glues each layer to its neighboring layer.
- Note: Emailing 3M to see if they have an adhesive to do this, should be the same adhesives that are used in standard N95 masks.
- Heat sealed or Edge sewn alternatives can be used for individuals that are sensitive to the adhesive.
- 

- Edge Sewn layers

Filter Material Combination Testing:

Test 1A: 3mm Honeycomb, 3 layers cotton round #1, 3mm Honeycomb -- (Fail for N95)
- No Vapor test performed

Test 2A: 3mm Honeycomb, cotton round #1, 3 layers of MERV 12, cotton round #1, honeycomb -- (Fail for N95 but promising)
- No Vapor test performed

Test 3: Honeycomb, 1 layers cotton round #1, 2 layers of Merv 12 , 1 layers cotton round #1, 3 layers of Merv 12, honeycomb, 2 layers of Merv 12, honeycomb -- (?? Very Promising)
- Hospital Vapor Test Results: Untested

Test 4: Honeycomb, 1 layers cotton round #4, 2 layers of Merv 13, honeycomb, 1 layers of Merv 13, 1 layers cotton round #4, 2 layers of Merv 13, honeycomb
- Open Air fit up review: Very Promising. Very similar to the air restriction felt on a rated N95 Mask
- Hospital Vapor Test Results: FAIL-20200324
- Pressure Tests:

Test 5: Honeycomb, 2 layers of Merv 13, 1 layers cotton round #4, 2 layers of Merv 13, 1 layers cotton round #4, 2 layers of Merv 13, honeycomb. Sending to lab testing… Round 2.

- Open Air fit up review: Very Promising. Little more air restrictive than a N95 mask.
- Hospital Vapor Test Results: Pass-20200324
- Pressure Tests:
- Notes:
- Lab Testing Results: Pending Results of “Test 6”

Test 6: Honeycomb, 1 layers of Merv 13, 1 layers Cotton round #4, 3 layers of Merv 13, 1 layers cotton round #4, 1 layers of Merv 13, honeycomb

- Open Air fit up review: This one breaths better than Test 5. Promising. Sending to lab testing if retests successful.
- Home Lab Vinegar Vapor Test Results:
- Hospital Vapor Test Results: FAIL-20200325 - But lasted until the end of the test and irregularities with person running test… Retest Needed, PASS-20200326
- Pressure Tests:
- Notes:
- Lab Testing Results: https://drive.google.com/open?id=1yupGFIhwD8AysjFTFQhwAgz6Ek0EjDfb
- CO2 Buildup Test:

Test 7: Honeycomb, 5 layers of Merv 13, honeycomb

- Open Air fit up review: This one breaths better than Test 6. Promising. Sending to lab testing if Hospital Vapor Test Results successful and “Test 6” successful.
- Hospital Vapor Test Results: PASS-20200330
- Pressure Tests:
- Notes:
- Lab Testing Results:

Test 8: 1 layers of Merv 13, 1 layers Cotton round #2, 3 layers of Merv 13, 1 layers cotton round #2, 1 layers of Merv 13

- Open Air fit up review: This one breaths better than Test 6. Promising. Sending to Hospital Vapor Test.
- Hospital Vapor Test Results: No Test, Sending to Lab
- Pressure Tests:
- Notes:
- Lab Testing Results: https://drive.google.com/file/d/1_RuipkcYF8WzaTJqf0Vsohv_ObHyBu_A/view?usp=sharing
    - Average of 99.9697% efficient over 3 samples at the 0.3 micron spec @ 32 liters/minute.
    - Average of 3.983mm/H2O of restriction @ 32 liters/minute.
    - Average of 99.9333% efficient over 3 samples at 2 data points each at the 0.3 micron spec @ 84 liters/minute.

- Average of 10.25mm/H2O of restriction over 3 samples at 2 data points each @ 84 liters/minute.

- Pulse-oximeter Extended Wear Test:
  - https://twitter.com/malamaker86/status/1248992962526302208
  - https://www.youtube.com/watch?v=h6pE7vO3Zqk
  - Results:

Minutes (Negative = No Mask, * = 70 jumping jacks + stretching)	Pulse-Oximeter Blood Saturation
-10	98%
-5	96%
0	97%
5	98%
10	96%
15	96%
20*	98%
25	97%
30	97%
35	97%
40*	98%
45	96%
50	97%
55	97%
60*	97%

  - Success: "Feeling fine. No tightness in my chest. Wearing a mask for an hour starts to need adjusting by the end but was able to wear it with very little discomfort. I'm going to call this a successful test."

- CO2 Buildup Test:

Test 8.1: 1 layers of Merv 13, 1 layers Cotton round #2, 3 layers of Merv 13, 1 layers cotton round #2, 1 layers of Merv 13

- Open Air fit up review: This one breaths better than Test 6. Promising. Sending to Hospital Vapor Test.

- Hospital Vapor Test Results: No Test, Sending to Lab
- Pressure Tests:
- Notes:
- Lab Testing Results:

Test 9: 1 layers of Merv 12, 1 layer of nanowave, 1 layers of Merv 12

- Filter Combination held under Open Source License: CC BY-NC (Creative Commons Attribution-NonCommercial)

- Open Air fit up review: Sending to lab (PH), Got light headed wearing this one within 5 minutes, suspect CO2 buildup. Need to do a CO2 test to see if that is the case.
- Hospital Vapor Test Results: No Test, Sending to Lab
- Pressure Tests:
- Notes:
- Lab Testing Results: https://drive.google.com/file/d/1_RuipkcYF8WzaTJqf0Vsohv_ObHyBu_A/view?usp=sharing
    - Average of 99.9697% efficient over 3 samples at the 0.3 micron spec @ 32 liters/minute.
    - Average of 6.433mm/H2O of restriction @ 32 liters/minute.
    - Average of 99.1433% efficient over 3 samples at 2 data points each at the 0.3 micron spec @ 84 liters/minute.
    - Average of 16.10mm/H2O of restriction over 3 samples at 2 data points each @ 84 liters/minute.
- CO2 Buildup Test:

Test 9.1: 1 layers of Merv 12, 1 layer of nanowave

- Filter Combination held under Open Source License: CC BY-NC (Creative Commons Attribution-NonCommercial)

- Open Air fit up review:
- Lab Testing Results: https://drive.google.com/file/d/1_RuipkcYF8WzaTJqf0Vsohv_ObHyBu_A/view?usp=sharing
    - Average of 94.13% efficient over 1 sample at 2 data points each at the 0.3 micron spec @ 84 liters/minute.
    - Average of 10.95mm/H2O of restriction over 1 sample at 2 data points each @ 84 liters/minute.
- CO2 Buildup Test:

Test #10: 1 layers of sterilization wrap #1

Testing Procedures and Standards:

Open Air fit up review:

- 1 hour wear.

Hospital Vapor Test:

- The test is using "Almond bitrex" vaporized combined with radical head movements and reading materials with the mask/filter on in a sealed environment.
- US Department of Labor (OSHA): https://www.osha.gov/video/respiratory_protection/fittesting_transcript.html

Pressure Tests:

- []

Flow Testing

- []

NIOSH Testing Standards

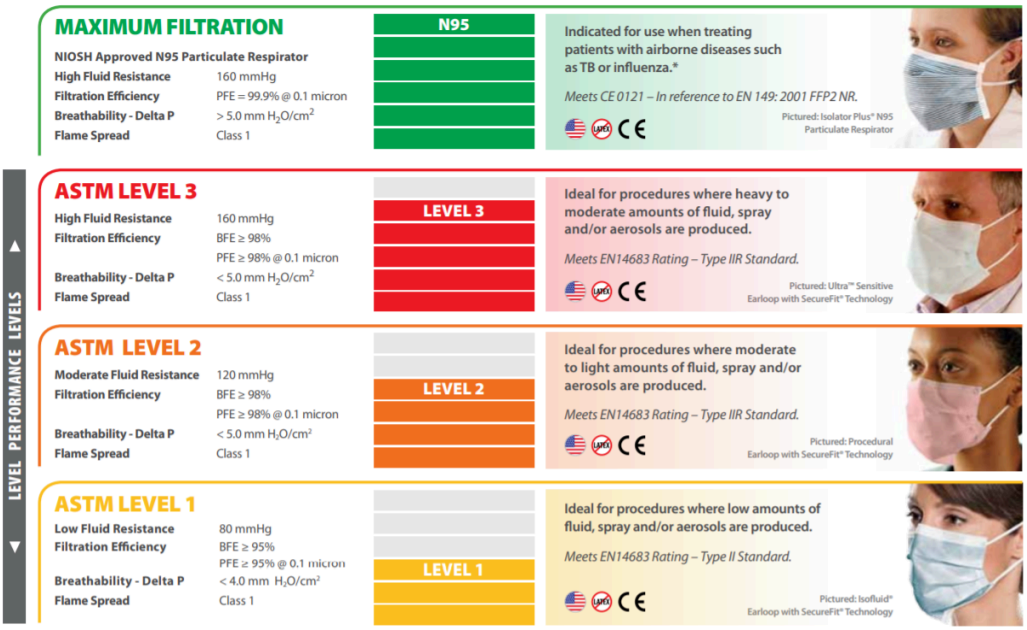
- Machine Used to test NIOSH and N95 Masks: TSI 8130/8130A (talked to Dan at TSI about this information)
- N95 standard particulate threshold: 0.2 micron
- 4 Testing labs were given by TSI regarding who has this equipment
    - 2020-03-24: Sent testing information off to Nelson Labs in Salk Lake City, Utah
    - 2020-03-24: Left Message with ICS Labs in Cleveland, OH
    - 2020-03-25: Nelson Labs responded, Sales team will be contacting shortly
    - 2020-03-25: ICS Labs called, missed call but told to email directly to lab tech's since non-essentials WFH. Sent testing information to ICS Labs
    - 2020-03-25: ICS Labs called and they are sending me a quote for an initial test to test the filter material combination. Results will be given for the test and then more extensive testing can be done using the mask if desired.
    - 2020-03-26: Received the quote from ICS labs. Also received the paperwork to send for official testing.
    - 2020-03-26: Paperwork returned to ICS labs for the "Test 6" testing. 12 Samples are going to be prepared at River City Labs in Peoria, IL. Sanitation will be completed first. Sanitation regimine [TODO: Define...stored in brain. See Cave Drawings below for a whiteboard. @jared]

Pulse-oximeter Extended Wear Test

1. 10 minute baseline, No mask, Pulse-oximeter reading at the start and every 5 minutes to follow.

2. 1 hour wearing of the mask with filter properly installed. Pulse-oximeter reading at the start and every 5 minute to follow, at every 20 minute interval doing 70 jumping jacks / stretching (touching tows, stretching arms, stretching neck).

Mask Levels and standards (Ref: PDF)



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- Halyard Health: Face the Facts (Ref: PDF)
    - Covers ASTM standards and specs high level.

Concepts:

Filtrate Material Compression Technique:

- The filter housing does the compression of the filtrate materials around the edges. Just as you would find in a respirator mask filter. In a respirator mask filter the compression is common along the edges of the filter.

Filters and Human contact

- Filters could be reused for more than single use if it cannot be contacted by contact contamination and as long as the filter does not become obstructed. Discussed this at length with SME in the R&D Division at Halyard Health (formerly Kimberly Clark) on 2020-03-31 @ 1:45pm CDT. Also filters can be dry heat sterilized to get use over a longer period of time. It is the direct contamination when applying and removing the N95 disposable masks that makes it a 1 time use filter!

Alternate filter classes to Merv Conversion Chart

- http://www.taicofilters.com/hvac-filters.html

Research: Filter Materials and Layering
(For Reference Only when printed) https://docs.google.com/document/d/1PvpCbRq_Sh6PIX0ziEDmQvnjWnJY5d0YOeTuWkOZNnA/edit?usp=sharing

Type	Application size range, um	New Class	Eurovent Class	Efficiency, %	MERV (approximate)
Coarse dust filter	>10	G1	EU1	<65	1
		G2	EU2	65 - 80	2
		G3	EU3	80 - 90	-
		G4	EU4	>90	-
Fine dust filter	1 to 10	F5	EU5	40 - 60	1 - 2
		F6	EU6	60 - 80	2 - 4
		F7	EU7	80 - 90	5 - 6
		F8	EU8	90 - 95	7 - 10
		F9	EU9	>95	11 - 13
HEPA	<0.3	H10	EU10	85	5 - 9
		H11	EU11	95	10 - 13
		H12	EU12	99.9	15
		H13	EU13	99.95	16
HEPV	<0.3	H14	EU14	99.995	17 - 18
ULPA	<0.3	U15	EU15	99.9995	19
		U16	EU16	99.99995	19 - 20
		U17	EU17	99.999995	20

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- H11/F9 seems to be sufficient and actually more efficient than 3M filtrete 1900 filters
- EN779: https://www.emw.de/en/filter-campus/filter-classes.html
- Working with a company in England and a person in Netherlands to get filters shipped over here.

Liters Per Minute

- "The average adult, when resting, inhales and exhales about 7 or **8 liters** of air per minute. That totals about **11,000 liters** of air per day. Inhaled air is about 20-percent oxygen." https://www.sharecare.com/health/air-quality/oxygen-person-consume-a-day

Assembly Tests:

Loose Layering:

- Easy to do. Assembly guide needed.

Sew Layering:

- [TODO]

Heat Seal layering:

- Rim sealing the furnace filter layers together

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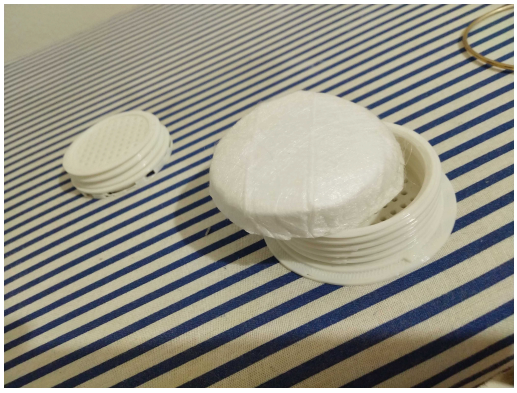
-  

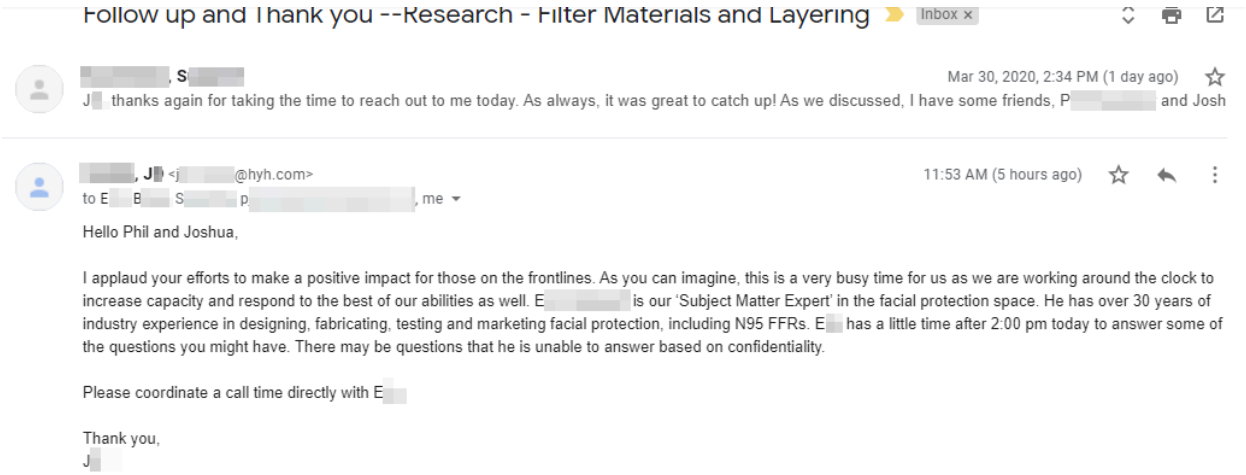
Spray Adhesion Layering:

- [TODO]

Conversation Notes:

2020-03-31 @ 1:45pm CDT - E from Halyard Health (formerly Kimberly Clark), SME R&D Division

- See ‘Concepts: Filters and Human contact’
- Cloth masks could be made out of single layer Merv 13 and/or Sterilization Wrap
- The cotton layer is a needed layer for breathability in a N95 mask and to separate the outer layers from the inner layers. Didn’t give a lot of details as to why but it has something to do with maintaining the integrity of the stop barrier in the middle of the filter.
- The proper outer layer typically used in N95 materials is a form of a statically charged polypropylene. But hard to come by right now because of the shortage so putting a merv outer layer can be an adequate substitute.
- Confirmed the proper machine to inspect this on is the TSI 8130.
- Suggested Heat sterilizing the masks.
- Air flow is key so finding that sweet spot is important to keep the user wearing the mask. Playing with the dividing layers that shield the inner layers is the key to finding a good air flow. Recommended building an air flow bench.

- N95 will see a flow rate drop 10-15mL of water. “Regular face mask” will see a flow rate drop of 3mL of Water.
- Confirmed that side compression of the filter materials is correct. I cannot remember why this was important but it was worth noting by the SME.
- Suggested just handing out the circles of materials and giving an assembly guide.
- ASTM standards highlighted in the call…
    - F2100 - Standard Specification for Performance of Materials Used in Medical Face Masks (https://www.astm.org/Standards/F2100.htm)
    - F2102 - Standard Test Method for Evaluating the Bacterial Filtration Efficiency (BFE) of Medical Face Mask Materials, Using a Biological Aerosol of Staphylococcus aureus (https://www.astm.org/Standards/F2101.htm)
- 

2020-04-03 @ 5:15pm CDT - J from Parker Hanifin, Filter SME in R&D Division in TN

- Discussed breathability of N95 masks and materials.
- Discussed nanofibers as being a more breathable solution but filters at the 0.3 micron @ 95% efficiency.
- PH is testing Nanowave Synthetic Filter Media (Merv 16) for spec (2020-04-06). If meets spec, I have permission to publish the results of the test and how/where to source.
- https://www.hollingsworth-vose.com/Documents/Product%20Literature-Filtration/NanoWave%20Synthetic%20Filter%20Media.pdf
- PH offered to test other filter combinations for free to support the Open Source project. Sending 3 sample combinations Monday (2020-04-06)

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Research: Filter Materials and Layering
(For Reference Only when printed) https://docs.google.com/document/d/1PvpCbRq_Sh6PIX0ziEDmQvnjWnJY5d0YOeTuWkOZNnA/edit?usp=sharing

Photos:

Certified N95 Hospital Mask:




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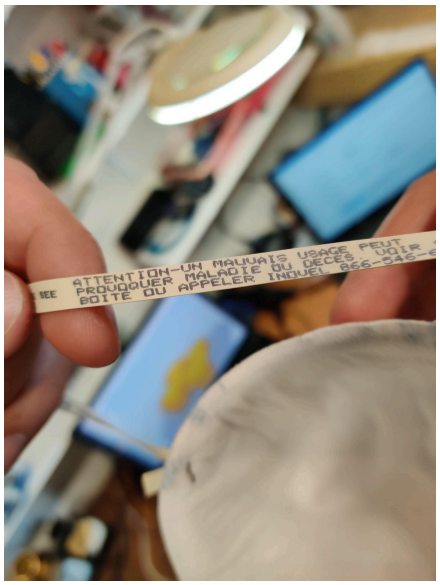

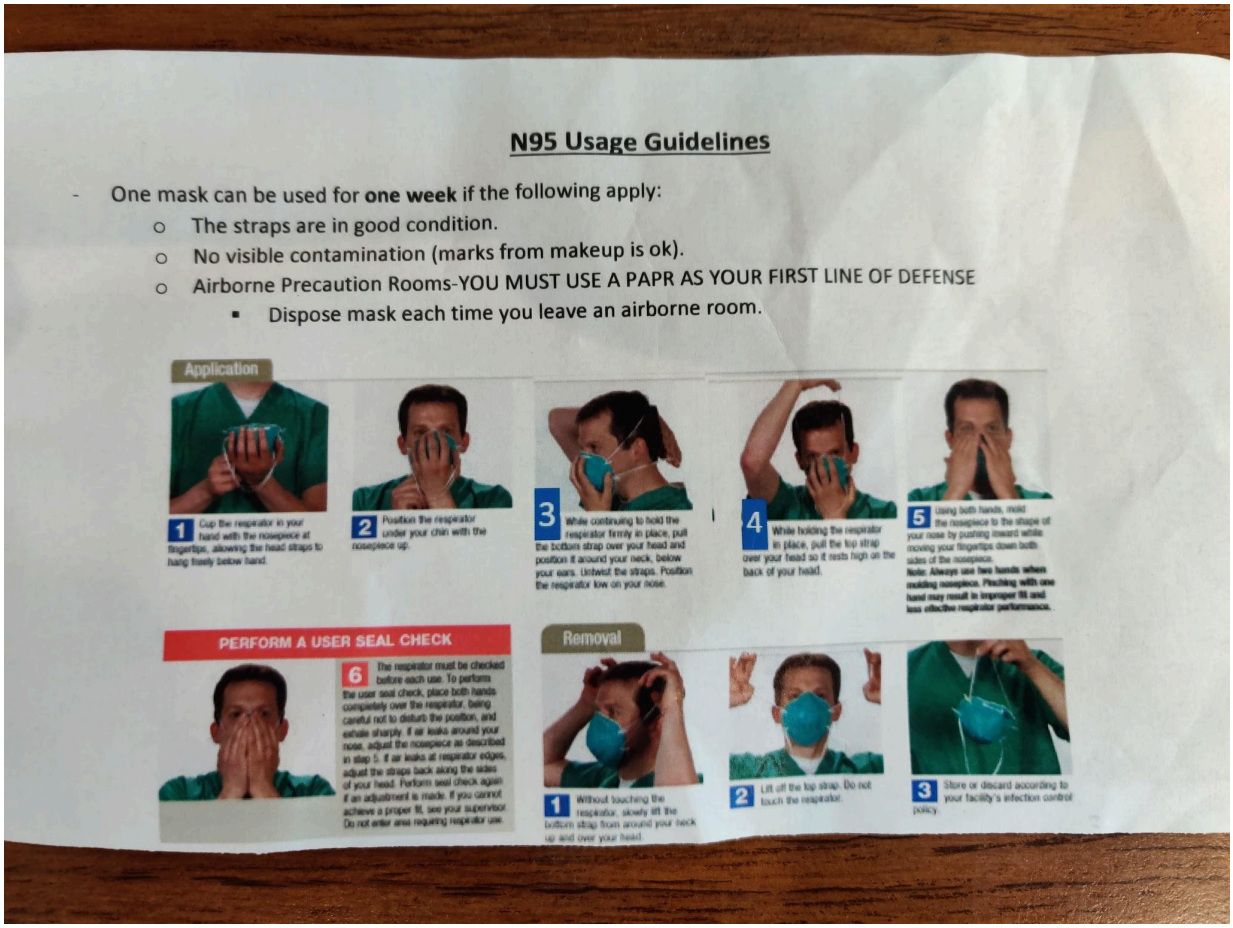

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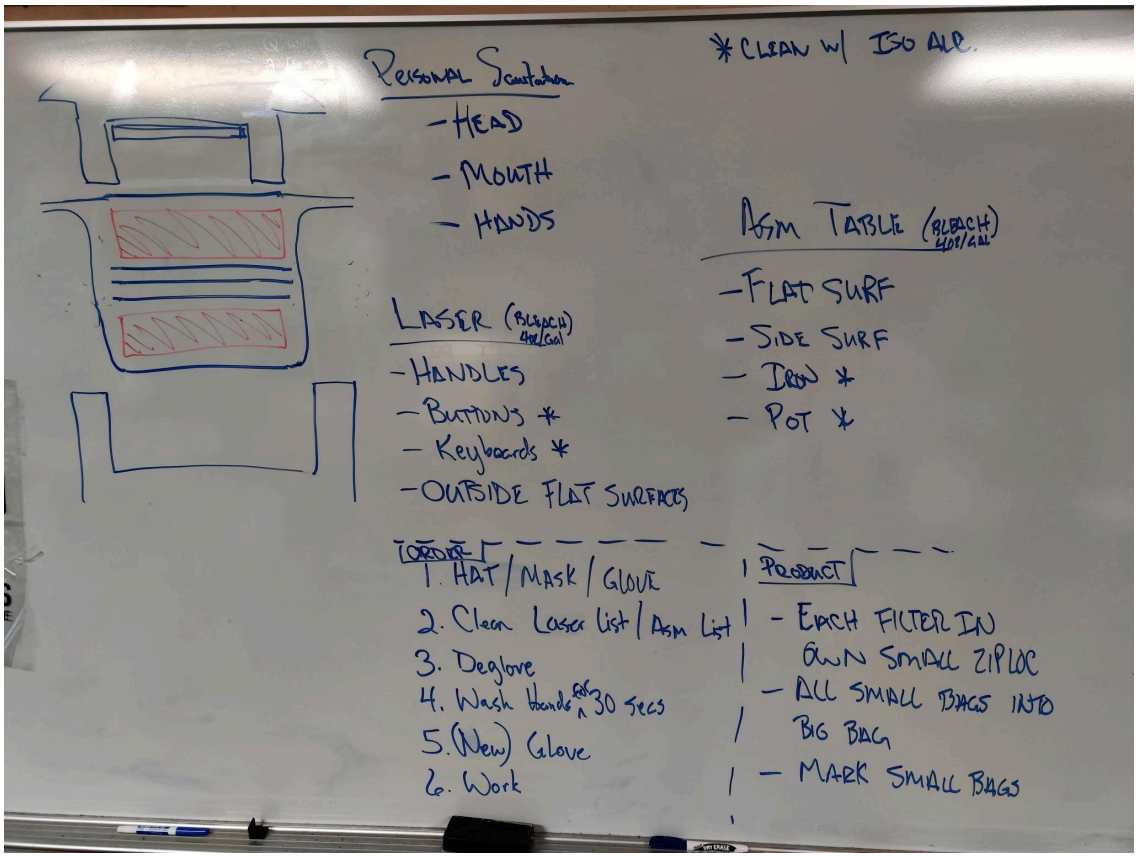

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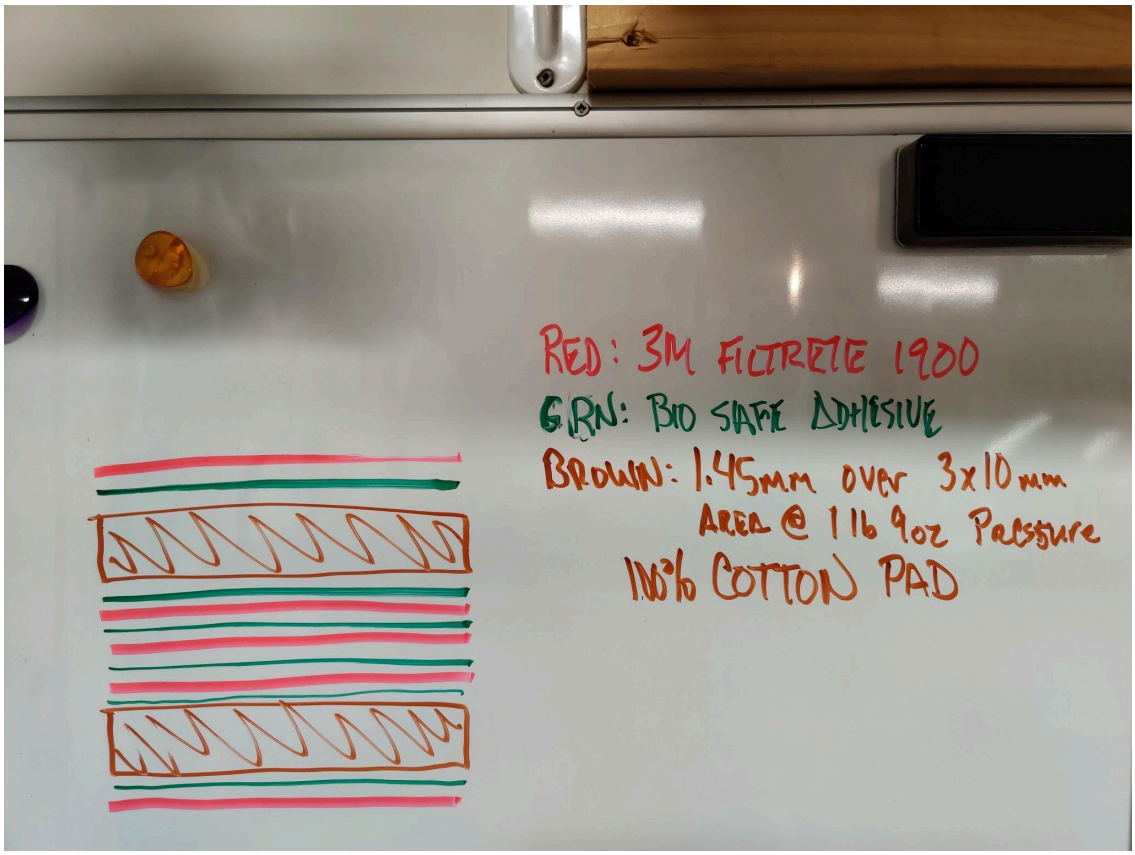

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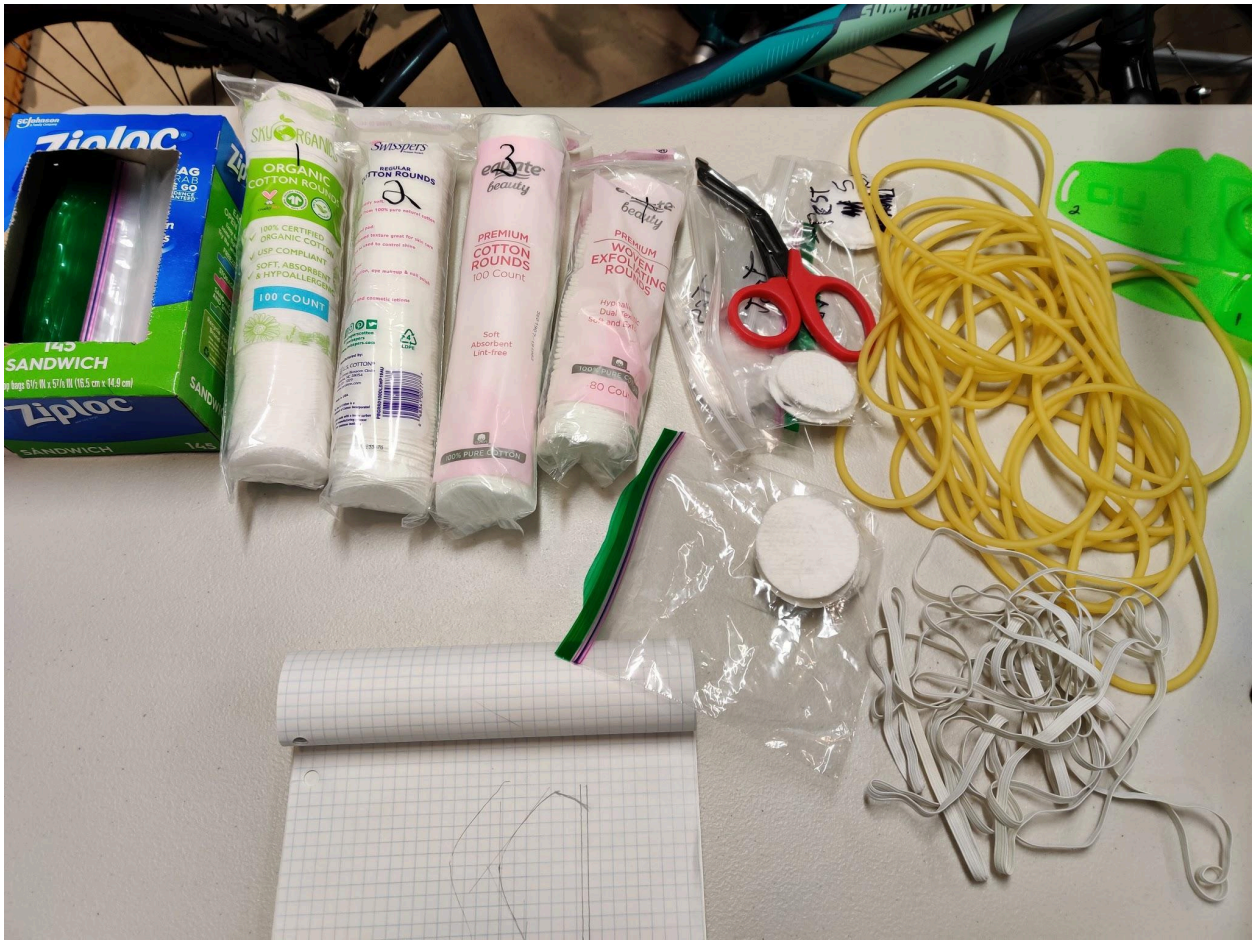
Materials



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