OPEN-SOURCE PERSONAL PROTECTIVE EQUIPMENT

POWERED AIR PURIFYING RESPIRATOR (PAPR)

In response to the overwhelming demand for Personal Protective Equipment (PPE) due to COVID-19, the Center for Medical Innovation at University of Utah Health has designed an enclosed Powered Air Purifying Respirator (PAPR) system to provide health care workers safe and reusable PPE when working with COVID-19 patients.

Designed to fully enclose the user, a PAPR system consists of a hood or helmet and a filtered respirator to provide those wearing the system a constant flow of clean air. This positive pressure prevents entry of unfiltered air and protects the health worker from inhaling aerosolized COVID-19 particles.

This document includes the specifications and instructions for assembly of this emergency use PAPR system. This system has been evaluated by Occupational and Environmental Health professionals and found to be safe for use with the exact components identified in this document, in the exact arrangement as described. This device is not a substitute for standard PAPR systems and is intended to supplement demand for protective equipment until standard PAPR systems can be obtained.

Any attempts to develop an identical PAPR system or similar systems should be evaluated prior to use by trained professionals in a certified testing facility. Many factors can impact the effectiveness of a PAPR system independent of the filtration components, including elevation, humidity, and other environmental considerations.

KEY SPECIFICATIONS FOR POWERED AIR PURIFYING RESPIRATOR:

- Required minimum flow rate between 6 ft\(^3\) and 9 ft\(^3\) per minute (170 L / min – 255L / min) for loose fitting hoods and shrouds; tight fitting masks require 110 L / min airflow
- Dual filtration system (environmental and in-line viral) maximizes longevity of system, provides protection 12x – 15x superior to N95 respirator.
- Higher flow rates may negatively impact effective filtration; CMI system optimized filtration levels with a 6.2 ft\(^3\) / min flow rate.
- Approximate operational life of 2-5 hours with fully charged battery, depending on model of fan used in motor assembly
## PAPR COMPONENTS – TECHNICAL & SOURCING INFORMATION

<table>
<thead>
<tr>
<th>Component</th>
<th>Details</th>
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<tbody>
<tr>
<td><strong>Hood-to-hose connector</strong></td>
<td><strong>3D printed connector with snap fit ring (2 pieces)</strong></td>
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<tr>
<td></td>
<td>- Designed to connect with 3M Versaflow hoods model #3M S-133L</td>
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<td></td>
<td>- Can be used to connect with 3M Versaflow hoods model #BE-12LB (formerly 522-02-03); requires additional plastic adapter</td>
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<td>- Computer aided design model for 3D printing available for download on CMI website</td>
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<tr>
<td><strong>Respiratory hose</strong></td>
<td><strong>Standard CPAP tubing, 4ft or 6ft (4ft preferred)</strong></td>
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<tr>
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<td>- CMI system uses: Sunset Healthcare Solutions 4ft CPAP tubing (#TUB004)</td>
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<tr>
<td></td>
<td>- <strong>Note</strong>: end caps of tubing measure 22mm interior diameter</td>
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<tr>
<td><strong>Viral filter</strong></td>
<td><strong>In-line viral anesthesia filter</strong></td>
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<td>- CMI system uses: Virobac II by King Systems</td>
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</table>
**AIR INTAKE FILTER CAGE**
- 3D PRINTED RIGID PLASTIC
- ALLOWS FOR AIRFLOW ON ALL SIDES TO PREVENT BLOCKAGE FROM GOWN
- COMPUTER AIDED DESIGN MODEL FOR 3D PRINTING AVAILABLE FOR DOWNLOAD ON CENTER FOR MEDICAL INNOVATION WEBSITE

**ENVIRONMENTAL FILTER**
2.5 INCH MERV 16 RATED FILTER DISC

**NOTES:**
- INSERTED BETWEEN FILTER BRACKET AND CAGE, THIS FILTER IS USED TO CATCH MAJORITY OF INITIAL AEROSOLIZED CONTAMINANTS
  - CMI SYSTEM USES: X6672 LENNOX HEALTHY CLIMATE 16X25X5 MERV 16 FILTER, LASER CUT INTO DISCS TO FIT AIR INTAKE

**ENVIRONMENTAL FILTER MOUNTING BRACKET**
- 3D PRINTED TO ENSURE FIT WITH SPECIFIC BLOWER MODEL FEATURES
- AIRTIGHT SEAL WITH MOTOR ASSEMBLY ACHIEVED WITH APPLICATION OF SILICONE
- COMPUTER AIDED DESIGN MODEL FOR 3D PRINTING AVAILABLE FOR DOWNLOAD ON CENTER FOR MEDICAL INNOVATION WEBSITE

**CENTRIFUGAL BLOWER**

**MODEL #** (SUPPLY CHAIN UNCERTAINTY MAY REQUIRE MULTIPLE MODELS):
- SANYO DENKI 9BMB12F201
- SANYO DENKI 9BMB12P2F01
- DELTA ELECTRONICS BFB1012EH-C18J

**NOTES:**
- IDENTIFY BLOWERS DESIGNED FOR STATIC PRESSURE RATING BETWEEN 1.5 - 3 INCHES OF WATER (373 – 746 PASCALS)
- IDEAL POWER OUTPUT BETWEEN 10W – 25W

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**MOTOR ASSEMBLY**
- AIR INTAKE CAGE
- ENVIRONMENTAL FILTER
- MOUNTING BRACKET
- CENTRIFUGAL BLOWER
- BLOWER OUTPUT ADAPTER
- WIRED CONNECTOR
<table>
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<tr>
<th><strong>MOTOR ASSEMBLY</strong></th>
<th><strong>BLOWER OUTPUT ADAPTER</strong></th>
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<tbody>
<tr>
<td>- BLOWER OUTPUT ADAPTER</td>
<td></td>
</tr>
<tr>
<td>- BOLTS &amp; CLIPS</td>
<td></td>
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<tr>
<td>- WIRED CONNECTOR</td>
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</table>

- 3D PRINTED TO ENSURE FIT WITH SPECIFIC BLOWER MODEL FEATURES
- AIRTIGHT SEAL WITH MOTOR ASSEMBLY ACHIEVED WITH APPLICATION OF SILICONE ON INTERNAL RIDGE
- COMPUTER AIDED DESIGN MODEL FOR 3D PRINTING AVAILABLE FOR DOWNLOAD ON CENTER FOR MEDICAL INNOVATION WEBSITE

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<th><strong>MOBILE POWER SOURCE</strong></th>
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12 VOLT RECHARGEABLE BATTERY
TALENTCELL RECHARGEABLE 12V 6000MAH

NOTES
- APPROXIMATE 2 TO 6 HOUR BATTERY LIFE DEPENDING ON MODEL OF CENTRIFUGAL BLOWER (HIGHER AMPERAGE RATING RESULTS IN SHORTER BATTERY LIFE)
- OPTIONAL PLUG IN FEATURE (STATIONARY USERS CAN PLUG IN AND RUN THE PAPR WHILE CHARGING THE BATTERY)

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<th><strong>BELT</strong></th>
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(Pictured above with battery)

THE BATTERY AND MOTOR ASSEMBLY CAN BE SECURED TO THE BELT USING CABLE-TIES.

**CMI SYSTEM USES:** STRAPWORKS DOUBLE ADJUST SIDE RELEASE BUCKLES (2") AND INDUSTRIAL WEBBING CORP. POLYESTER WEBBING 4-PANEL 2" X 100 YARDS

NOTES
- REQUIRES ADDITIONAL HEAT SHRINK TAPE OR WIRE SLEEVE TO PROTECT EXPOSED WIRES FROM BLOWER AND ENSURE CONNECTION

**THREADED BOLTS WITH HEX NUTS AND WIRE CLIPS TO SECURE FILTER TO BLOWER**

- QTY 2: TWO 8-32 2” STAINLESS PHILIPS BOLTS
- QTY 2: 8-32 STAINLESS STEEL NYLON LOCKING HEX NUTS
- QTY 2: ¼” NYLON CABLE CLAMPS
MOBILE BATTERY CONNECTOR WIRE ASSEMBLY

REQUIRED MATERIALS
- Centrifugal blower with uncovered wire-harness
- Dc power source connector
- Heat-shrink tape – 0.75" width
- Wire sleeve
  - 11" length
  - 2.5" length

ASSEMBLY INSTRUCTIONS FOR BATTERY PACK CONNECTOR WIRE
1. Cut ¾” off the end of the yellow wire. Make sure it is cut back far enough so there is not any exposed wire. Yellow wire is unused – do not strip
2. Tape wire ends of fan together to assist in sliding sleeving over (if needed)
3. Slide sleeving over wires until it touches the fan body
   - Shrink sleeving in place with directed heat source
   - **Caution** – do not get burned by heat source
4. If necessary, trim fan wires (red & black) so they are even in length – leave ¼” of exposed wire
5. Attach wires to connector using phillips #0 screwdriver
   - Red wire to (+) terminal
   - Black wire to (-) terminal
   - Hand tighten screws
6. Tightly wrap build up tape around wires near connector – slide tape so it is tight against connector
7. Install sleeving over connector, centered over wire connections
8. Shrink sleeving in place with directed heat source
   - **Caution** – do not get burned by heat source
REQUIRED MATERIALS

- Centrifugal fan with wrapped connector wire
- Filter cage
- Lower filter bracket
- Environmental filter disc
- Hardware
  - 2 bolts
  - 2 hex nuts
  - 2 wire clips

ASSEMBLY INSTRUCTIONS FOR MOTOR

1. Assemble clips to hardware in orientation shown (2X)
2. Install hardware with clips into fan housing from direction indicated, 2 locations
3. Install filter into upper housing as shown – ensure it is in place on all edges
4. Insert lower housing into upper housing and align holes. Push together until seated
5. Apply a bead of Silicone material to groove on underside of lower fan housing. Apply enough silicone to fill groove, it should be slightly higher than groove edge
6. Install Filter assembly onto fan assembly **CAUTION**—The holes in fan assembly are very tight do not force screws through the hole. If needed the screws can be threaded into the fan housing
7. Tighten nut until snug onto bolt using Philips head screwdriver and supplied wrench (2X) **CAUTION**—The Fan housing material can easily be broken, use caution when tightening hardware.
8. Apply a bead of silicone to the inner side near the top of the outlet port (4 sides)
9. Place the outlet port into the fan unit. Push until fully seated
10. Apply silicone to the gap between the housing and fan unit. Do not overfill apply enough only to close gap
11. Review for proper assembly, clean any silicone as required.
RESOURCES & CONTACT

ADDITIONAL RESOURCES ARE AVAILABLE ONLINE AT THE CENTER FOR MEDICAL INNOVATION WEBSITE:

UOFUHEALTH.UTAH.EDU/CENTER-FOR-MEDICAL-INNOVATION/

INCLUDING

- DESIGN FILES FOR DOWNLOAD OF 3D PRINTED COMPONENTS
- OTHER OPEN-SOURCE PPE PROJECTS
- TRAINING MATERIALS FOR ASSEMBLY & USAGE
- CONTACT INFORMATION

FOR MORE INFORMATION, PLEASE CONTACT

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