THIS DEVICE AND THE ASSOCIATED COMPONENTS ARE **NOT** ENDORSED OR APPROVED BY THE FDA

This assembly video is provided as reference material only, the design and components utilized are not approved for emergency resuscitation. This video encompasses building a theoretical “what-if” scenario and presenting a conceptualized solution. This video and the device shown should not be utilized without the assistance of properly trained and licensed medical professionals.

WE DO NOT RECOMMEND THE USE OF THIS DEVICE WITHOUT THE APPROPRIATE AHJ REVIEWS AND APPROVALS

Design Parameters

Clinical Respiratory Therapy Project requirements

1.) Ability to control a tidal volume (or at least within a range of 4-6 ml/kg Ideal Body Weight (IBW)). – 100ml/second to 750ml/second volume - 60 L/min up to 100L/min

2.) Ability to control a Respiratory Rate up to 35 breaths/min – 2 adjustable controls, inhale "on time" and exhale "off time" 1 second inhale time, 2 second exhale time (adjustable)

3.) Ability to achieve a PEEP up to 20 cmH2O – Ability to control pressure in circuit incrementally from 5 cmh2o (1.97047 in. of water) to 30 cmh20 (11.8228 in. of water). With a safety high pressure emergency vent of circuits at 40 cmh2o (15.7638 in. of water).

4.) Ability to bleed in oxygen – blend in oxygen or replace 100% of volume with 100% O2

5.) Ability to monitor pressure – visual manometer in cm/h20 or equivalent

6.) High pressure alarm and low pressure alarms/vents

7.) Viral Filter in line .2micron particle rating

Optional

7.) A pressure transducer allowing patients to increase the Respiratory Rate above what is set by creating negative pressure

Goals/Parameters from DF Manufacturing

1) Use only off the shelf parts
2) Must operate continuously for a min. of 1hr maximum of 5 days.
3) Must be reliable for continuous use
4) Cleanable can be quickly Sanitized
5) Affordable as possible
6) Portable (moved by 1x person)
7) Easy to assemble, repair, replace – no special tools or training
8) Avoid imported/long lead items
9) Pre-fabbed components if possible

Emergency pressure safety vent (depth of pipe below surface of water)

1” = 2.53 cmh2o

11.82” = 30 cmh2o

15.76” = 40 cmh2o

PEEP (exhale positive pressure if required)

1.97” = 5 cmh2o

3.94” = 10 cmh2o

7.88” = 20 cmh2o

11.82” = 30 cmh2o

PSI equivalents

1 cmh2o = 0.0142 psi

30 cm h2o = 0.426 psi

Shane, Cylix

From: Striggow, Christian <Christian.STRIGGOW@scc.spokane.edu>
Sent: Friday, April 03, 2020 10:36 AM
To: Bryant, Darrell L; Shane, Cylix; Hutchison, Spencer M
Cc: Zhang, Fan; Matt Whigham
Subject: Re: [EXTERNAL] Breathing pressure numbers

Hello,

Yes your delta pressure of +3.0 cmH2O to -2.0 cmH2O is very accurate for a healthy individual breathing at rest. As I shared with Cylix a few days ago, the equation of motion for the respiratory system is a useful tool to help conceptualize the movement of bulk gas into the lungs, and how much pressure is required to move a given volume of gas into the lungs (approx. 500 ml or 0.5 L / breath).

During normal restful breathing, our diaphragm drops, creating negative pressure in the thoracic cavity and alveoli of the lungs relative to atmospheric pressure (0 cmH2O), usually in the range of -2 to -3. Gas flows from a high pressure (0 cmH2O) to a low pressure (-2 cmH2O). Gas continues to flow until a pressure equilibrium is reached between the alveoli and the atmosphere (0 cmH2O). Then the diaphragm moves back up into the thoracic cavity, compressing the volume of gas in the alveoli and increasing pressure to above atmospheric (+3 cmH2O). Gas flows out of the lungs until again an equilibrium is achieved (0 cmH2O). This is healthy at rest.

Patients with lung disease have either an increase in airway resistance (diameter of the airways becomes narrow from smooth muscle contraction, or secretions in the airways), or they have a decrease in lung tissue compliance (the alveoli change from being like a balloon to more like a golf ball - they become very stiff, and sometimes collapse). In both of these cases it takes a larger delta pressure to move the same volume of gas into the lungs (0.5 L / breath). Often patients are unable to generate the delta pressure required to move this volume on their own - hence they need a ventilator.

A ventilator works by increasing pressure at the airway opening (mouth/ trachea) relative to what is in the alveoli. If alveolar pressure is 0 cmH2O, and pressure at the mouth / trachea is 20 cmH2O, gas will flow into the lungs. This brings us to the equation of motion for the respiratory system:

Normal breathing at rest: Pmusc = (Vol / Compliance) + (Resistance x Gas flow)

Positive pressure breathing with a ventilator: Pvent = (Vol / Compliance) + (Resistance x Gas flow)

In general this is a mathematical equation, both sides must be equal. With modern day ventilator technology we can only control one side of the equation, either we control precisely how much volume is delivered to the alveoli (the volume that leaves the ventilator), or we can control how much pressure is applied to the airway opening (the Pvent in the equation), but never both at the same time.

Cylix has developed a very basic pressure ventilator. His ventilator increases pressure in the circuit which is connected to the mouth / trachea relative to alveolar pressure, causing gas to flow into the alveoli until pressure equilibrium is met, or the set I time elapses, or the 40 cmH2O pressure relief activates.

Looking back to the equation of motion for the respiratory system, we see that we are controlling Pvent, therefore the amount of volume delivered to the alveoli is largely dependent on the compliance of the alveoli, and the resistance of the airways. Sicker patients will require larger pressures to achieve a normal size volume with each breath.

Back to the original question of how much pressure is safe. Anything above a normal delta pressure of around 3 cmH2O is potentially injurious to the lungs, because it is not physiologic. With each mechanical breath at a greater pressure we are causing stress and strain of lung tissue. Therefore it is always our goal to ventilate with the lowest possible pressure necessary to achieve normal volume delivery, and of course remove the ventilator as soon as possible! Many studies have established an upper limit of alveolar pressure of around 30 cmH2O as being "safe" or "lung protective" when applying ventilation, and more importantly a "driving pressure" of no more than 15 cmH2O.

You can imagine then, if alveolar pressure is 0 cmH2O, our maximum airway pressure should be 15 cmH2O. If we apply PEEP to our patients during the expiratory time, we have essentially raised our alveolar baseline pressure above 0 cmH2O. For example, if I set a PEEP of 10 cmH2O, my alveolar pressure now never drops below 10 cmH2O, and I can now increase my airway opening pressure to 35 cmH2O and still achieve a safe driving pressure of 15 cmH2O.

Keep in mind that optimal PEEP settings are unique to all patients, and we cannot assume that we will set a PEEP of 10 for all patients, also, each patient has different compliance and resistance, therefore the airway pressure we apply will be different for each unique patient.

These are just very basic concepts, and this brief synopsis only scratches the surface of ventilator physiology, and safe mechanical ventilation.

Hope this helps some. Mechanical ventilation is a very complex subject, and not one that can be easily learned in a few weeks - it takes years.

Christian Striggow M.Ed., BSRT, RRT-NPS
Program Director, Respiratory Care
Spokane Community College
(509)-429-8184

From: Bryant, Darrell L <BryantDL@st-lukes.org>
Sent: Friday, April 3, 2020 9:22 AM
To: Shane, Cylix <Cylix.Shane@providence.org>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Striggow, Christian <Christian.STRIGGOW@scc.spokane.edu>
Cc: Zhang, Fan <Fan.Zhang@providence.org>; Matt Whigham <matthewwhigham@gmail.com>
Subject: RE: [EXTERNAL] Breathing pressure numbers

Thank you for the input and work you have all done. I am not sure if this helps or muddies the waters…

The thing to remember is that if a patient is intubated or has a trach, the upper airway is bypassed and pressure is applied directly to the lungs.

From: Shane, Cylix [mailto:Cylix.Shane@providence.org]
Sent: Friday, April 3, 2020 7:34 AM

To: Bryant, Darrell L; Hutchison, Spencer M; Christian Striggow
Cc: Zhang, Fan; Matt Whigham
Subject: FW: [EXTERNAL] Breathing pressure numbers

Gentlemen,
Please see below, I know Grahams team is basing their concepts off of diving pressures and how respiration works. I am going to chew through the data and concepts he has provided below but if you could help me by reviewing the information as well I feel we may be able to help their team improve their design and minimize risk to patients. Let me know what your thoughts are. It is good to give the community a couple of well-thought out design options for emergency ventilation. If you have quick insight into the parameters his team wants to verify below, let me know and I can help convert over to his FSW units so the engineering teams are all speaking the same pressure/volume language.

Thanks!

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From: Graham Hawkes <graham@subseasystems.com>
Sent: Friday, April 03, 2020 7:02 AM
To: Shane, Cylix <Cylix.Shane@providence.org>
Cc: David Liddle <david.e.liddle@gmail.com>; Julie Silverman <juliesilverman.atcg@gmail.com>
Subject: [EXTERNAL] Breathing pressure numbers

Good morning Cylix.

Cylix, Thanks for those breathing pressure numbers, which confirm first rough test yesterday, don't want to add to your work, so the following is optional.

Measured my own max breath pressure at approximately +24 and -16 inches of water just to get quickly "dialed in. The measurement error I am ignoring assuming greater human variation (unknown).

So curious what the safe breathing pressures (referenced to barometric pressure and measured at mouth or noze) for weaken lungs of elderly patients. Since my mantra is "do no harm" as WAG working with target of only 10 % of my (72 year old) max pressures with a safety factor of 2 (typical sub practice) so 5% of my maximums. As said just a WAG guess, hopefully on the safe side but experimented with and first estimate is useful breathing assistance. Any comments please. .

Hence our working goal is a maximum +1.2 (+- 0.2) inches water on inhale and -0.8 i(+- 0.2) inches of water on exhale... pressures measured in mouth piece as differential pressure relative to barometric pressure.

Note since human body (except lungs) is effectively fluid and seems to adapt (known from diving) perfectly to ambient pressure which has been shown to be ok to extreme pressure (Comex max depth mixed gas chamber dive to 2000 fsw approximately 888 psi, or 54,000 inches of water), relative to which possible variations in atmospheric pressure are trivial and so are safely neglected. Since ambient pressure is equalized in the human body. Hence we use a

manometer to measure the pressure differential of breathing. Importantly however while chemical process's may be modified by changees in ambient pressure, breathing effort is not. The principle we are using is that the human body for mechanical principles adapts perfectly to ambient pressure (equalization) so variations within barometric pressure can be ignored.

Coverted to cm our target delta breath gas pressure range referenced to ambient (barometric pressure) is +3.0 cmwater to -2.0 cmwater with accuracy of +- 0.5 cm water (**so worst case is actual +3.5 to -2.5 cm water) which should do no harm** .

Today I plan convert our manotemter to cm from inches by reclining at 23 degrees so will give 1/0.394 conversion so that inch scale is will read pressure in cmwater and conform with medical practice.

David please let me know if this is too much info. but it serves to help document the process.

Graham

FULL TEAM DISCUSSION MAIN THREAD

(this has been the main one, there are core team threads)

Shane, Cylix

From: Shane, Cylix
Sent: Tuesday, April 07, 2020 3:51 PM
To: 'AK Srouji'; Gillespie, Susan M; Bryant, Darrell L; 'Christian Striggow'; Hutchison, Spencer M; 'Anthony J Schoen'; 'Tony Maiani'; Martin, Rosemary Y; 'daisy.shane07@gmail.com'; 'Marjorie Thompson'; 'Michael Frank'; Hunt, Jason E; Thomsen, David C; 'David Paulus'; 'Thompson, Travis'; Ruggenberg, Donald J; 'zac@additiveamerica.com'; 'goldine@umich.edu'; Zhang, Fan; 'curtha@amazon.com'; 'Matt Whigham'; 'Tate Phillips'; 'mylesbeetle@gmail.com'; 'nguye343@cougars.csusm.edu'; 'Matt Landoe'; 'Graham Hawkes'; jamie@m5industries.com; Milne, John; Herr, Alex
Subject: RE: Ave Maria Progress Update R5

Team,
Just wanted to give everyone a heads up that we ran additional testing on Friday to verify that our design improvements made the appropriate impacts. We have confirmed that the prototype is functional and consistent. The results meet the requirements for temporary rescue breathing/ventilation – we saw consistent results of approx. 500ml of air being delivered at 4psi, 1 second inhalation, 2 seconds exhale, we also had 6 PEEP set in the circuit using a water bubbler with good results. I will document all of the components, assembly, and specifications for those in low-resource areas to leverage as needed. I will have uploaded a video of the R5 version of our design. Video editing and document preparation is going to take significantly longer than the actual device assembly, but knowledge is the main thing we are sharing!

Here is our latest revision and final prototype layout. Thank you everyone that helped participate so far. I will continue looking into the viral filtration module and an acceptable mask or intubation tube otherwise, we have succeeded!

https://youtu.be/DZlEKZ3Wx4k

Thank you everyone for your contributions towards this endeavor. We have substantially completed this project!

Thanks
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From: Shane, Cylix
Sent: Monday, March 30, 2020 5:34 PM
To: AK Srouji <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; zac@additiveamerica.com; goldine@umich.edu; Zhang, Fan <Fan.Zhang@providence.org>; curtha@amazon.com; Matt Whigham <matthewwhigham@gmail.com>; Tate Phillips

<tateandphillips@gmail.com>; mylesbeetle@gmail.com; nguye343@cougars.csusm.edu; Matt Landoe <MattL@atsinlandnw.com>
Subject: Ave Maria Progress Update R4

Team,
Please see the updated progress video. I still need assistance calculating the correct spring rate/turns on the wingnut to increase cmH2o. If you know anyone that could help me with that I would love a quick video conference call to explain the layout and listen to suggestions, let me know! We had good test results on the servo lung patient simulator. There are some improvements to the exhale circuit that we need to sort out. We also need to build a manual manometer and we are developing the viral filter concept.

Please feel free to review, provide feedback, and share.
https://youtu.be/Bk8ffkmZGaU

Thanks!

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From: Shane, Cylix
Sent: Thursday, March 26, 2020 7:47 AM
To: 'AK Srouji' <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; 'Christian Striggow' <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; 'Anthony J Schoen' <aschoen@zagmail.gonzaga.edu>; 'Tony Maiani' <TonyM@mwengineers.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; 'daisy.shane07@gmail.com' <daisy.shane07@gmail.com>; 'Marjorie Thompson' <marjorie0thompson@gmail.com>; 'Michael Frank' <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; 'David Paulus' <davidpaulus@hotmail.com>; 'Thompson, Travis' <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; 'zac@additiveamerica.com' <zac@additiveamerica.com>; 'goldine@umich.edu' <goldine@umich.edu>; Zhang, Fan <Fan.Zhang@providence.org>; 'curtha@amazon.com' <curtha@amazon.com>; 'Matt Whigham' <matthewwhigham@gmail.com>; 'Tate Phillips' <tateandphillips@gmail.com>
Subject: Power sketch

Team,
Please see the attached quick crude sketch to help visualize the concept for the energized components.
Thanks.

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From: Shane, Cylix
Sent: Thursday, March 26, 2020 6:01 AM
To: AK Srouji <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; zac@additiveamerica.com; goldine@umich.edu; Zhang, Fan <Fan.Zhang@providence.org>; curtha@amazon.com; Matt Whigham <matthewwhigham@gmail.com>; Tate Phillips <tateandphillips@gmail.com>
Subject: RE: Ave Maria (AM) Vent next steps

Team,
To our power supply and battery team members! Now is your time to shine. I am ready to get your help suggesting the best "Off-the-shelf" power inverter or combination of products from the hardware stores. You can use any products on the Grainger website, Home Depot, Lowes, or Ace Hardware to accomplish this task. Nothing rare, complex, or with significant long lead time constraints. We want to power our 24vAC power transformer with a battery pack if possible and lessen the risk of people trying to wire up their own 120vAC pig tails. As Matt phrased it make our design "Less Zappy". Matt identified the potential to use an off the shelf 12v DC to 120v AC power inverter (good idea). Do you have any better/safer power supply solutions to recommend? Can you validate the power consumption and requirements for the 1" sprinkler valves?
https://www.grainger.com/category/fleet-and-vehicle-maintenance/automotive-electrical/automotive-battery-equipment/installed-automotive-battery-chargers-and-inverters/inverters
Looking for recommendations for the most effective off the shelf battery/inverter combos!

Attached is the spec sheet on the power supply and controls.

Also we have DIY'ed the peep valve, meaning we can design and build our own spring diaphragm vent in under 1 minute if we have the right springs (or spring modifications, i.e. cutting coils) spec'd from the off the shelf solutions (photo attached). We are going to improve the design for reliability however the base proof of concept has been successful for DIY Peep and Emergency vent modules. It was crude but effective. I utilized a 1" PVC plug, and a toilet fill valve seal as the diaphragm. Added a spring, through-bolt, wing nut to increase PEEP or cmH2o required. We just need to reduce any risk of thread wear or catching on the pvc by installing a bushing and shoulder bolt to compensate for the friction. I still need help with spring calculations based off of this design, or alternative off-the shelf rapid fabrication ideas any of you may have to replicate a controllable spring diaphragm assembly. Keep up the good work, love the input and collaboration.

I was interviewed over the phone today by Miles O'Brien from PBS Frontline, they intend to fly out to Spokane for a video interview of our progress. If you are a core team member and feel you should be recognized for your efforts with this news/media source please let me know and I will share the interview schedule with you.
https://en.wikipedia.org/wiki/Miles_O%27Brien_(journalist)

Thanks!

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From: Shane, Cylix
Sent: Wednesday, March 25, 2020 10:01 AM
To: AK Srouji <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; zac@additiveamerica.com; goldine@umich.edu; Zhang, Fan <Fan.Zhang@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; curtha@amazon.com
Subject: RE: Ave Maria (AM) Vent next steps

Team,
Updated layout per RT team review this morning. Please review and let me know if you see any issues with the proposed concept revisions thanks.

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From: Shane, Cylix
Sent: Tuesday, March 24, 2020 5:14 PM
To: AK Srouji <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; zac@additiveamerica.com; goldine@umich.edu; Zhang, Fan <Fan.Zhang@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; curtha@amazon.com
Subject: RE: Ave Maria (AM) Vent next steps

Team,
Attached is an updated layout per recommendations from RT and Engineering groups. Please review and let me know if you see any issues. If there are none, I will proceed with streamlining the part selections to maximize the results of each modules concept. I will be looking at design for manufacturing - reliability, availability, ease of assembly, weight, etc.

Thanks!

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From: Shane, Cylix
Sent: Monday, March 23, 2020 8:38 PM
To: AK Srouji <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; zac@additiveamerica.com; goldine@umich.edu
Subject: RE: Ave Maria (AM) Vent next steps

Good evening,
I have updated and made a more presentable initial proof of concept for team review. https://youtu.be/higPNIBApnA
Please see
Thanks!

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From: Shane, Cylix
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To: 'AK Srouji' <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; 'Christian Striggow' <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; 'Anthony J Schoen' <aschoen@zagmail.gonzaga.edu>; 'Tony Maiani' <TonyM@mwengineers.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; 'daisy.shane07@gmail.com' <daisy.shane07@gmail.com>; 'Marjorie Thompson' <marjorie0thompson@gmail.com>; 'Michael Frank' <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; 'David Paulus' <davidpaulus@hotmail.com>; 'Thompson, Travis' <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; 'zac@additiveamerica.com' <zac@additiveamerica.com>; 'goldine@umich.edu' <goldine@umich.edu>
Subject: Ave Maria (AM) Vent next steps

Team,

Thank you to everyone who has helped so far in the development of this concept. Please let me know as soon as possible if you would no longer like to participate and I can remove you from the communications and design challenge requests. I have started to share the concept with our online communities, this has helped get other creative solutions suggested and garner support/initial feedback. All feedback has been positive so far with no issues identified with our concept. I know all of your time is valuable and I appreciate every minute you have donated so far! Please message me and let me know if you would like to be publicly recognized as a participant and contributor to the project otherwise I will leave your participation as confidential. Our next steps are to continue testing, balancing, and refinement of the off-the-shelf emergency solution. As the concept is functional, I now need help with validating and completing calculations for specific materials. I need engineering assistance solving the following challenges, or I need your help finding a resource whom you feel is knowledgeable enough to answer the following design validation/challenges.

I can complete these tasks on my own but it will consume precious time, so any assistance would be greatly appreciated. If you want to work on a particular task, please let the team and I know. If you are in need of some additional support, we can form digital break-out-groups to collaborate so we do not waste any time on duplicate efforts.

Engineering support needed:

- Challenge: Spring Rates
    - What off the shelf compression spring choice would have a spring rate/strength equivalent to 50 cmh2o?
    - Which one would have the equivalent of 5 cmh20?
    - What is the easiest way to field test that the compression spring in my hand meets the spec?

    I will measure the current diaphragm surface area, pipe diameter, rod size, travel distance, etc. so the correct spring can be spec'd. but I need help with the calculations to find the off-the-shelf equivalent. We have a catalog of technical specs online for available springs that we can match it to if we know what we are searching for.

- Challenge: Valves/Regulators
    - Which off the shelf valve types offer the most precision/adjustments/consistency (gate valves, needle valves, ball valves?)
    - Range of acceptable valve sizes is 1/2"- 2" (most likely in the 1-2" range though for required air flow rates/volumes).

- Challenge: Regulators
    - Which off the shelf air compressor regulators are the most reliable and accurate?
    - Which ones available that have low range gauges and adjustments off the shelf?
    - Our operating PSI range is likely to be below 5psi in the expansion tank at any time
    - Do we want to install a secondary exhaust pop-off vent for the expansion tank in case it exceeds the feed regulator? (5-10psi will cause venting?)

- Challenge: Solenoids
    - Which off the shelf sprinkler solenoids are the most reliable/durable for short cycling?
    - I've seen solenoids with labels like "professional grade" what does that mean in regards to performance/reliability?
    - (Assuming we stick to a 24v off the shelf solenoid system)

- Challenge: Filtration
    - We need to Spec a filter or filter bank from off the shelf materials that garners a .2 micron filtration equivalent
    - The surface area of the screen will be approximately 3.29" maximum (surface area of the inside of a 2" pvc pipe)

- Determine how much flow resistance we need to account for in the line (adjust PSI)?
- How deep will the filter need to be (I can build a modular filter can with a 2" threaded riser of the appropriate length if you spec the filter depth needed).

- Challenge: Flow Mapping
  - Need to map out the models for the equivalent PSI + valve position combinations to garner required tidal flow and inspiratory rates
  - Determine how long the feed valve stays open (2-6 second inspiratory rates?)
  - What position the flow valve should be in for the appropriate air volume.
  - If we have a curve or general approximation, we can give guidance- i.e. "At 3 Psi, w/ the 1" PVC Ball valve at 2'oclock position, and a typical inspiratory time of 2 seconds, tidal flow will be _____ "
  - We just need to hit the most common averages, think of a user adjusting a valve, it will be either by full turns or typically by 1/8 to 1/4 turns- our respiratory team has provided us with the typical required flow ranges.
  - We know the I.D. of the pipes being used, the reducers, couplers used, the PSI required in the pipe can be determined, coefficients of friction from the types of materials used can be determined (PVC, rubber, vinyl hose) we know the open/close ranges (2-6 seconds) and the patient required volumes. Lets reverse engineer the flow model in the system, if we do the calcs right, it should line up with the spirometer readings at the POC. Then we can use that info to adjust the various pressures and valve positions, or revisit the piping size or layout to increase/decrease volumes and pressures as needed to meet patient requirements.
  - We have a majority of the baseline variables now that I can measure for the team, just let me know what dimensions are important, since the parts are off the shelf we should be able to get the manufacturers specs easily as well. If it is not readily available online I can call the manufacturer and request cut sheets. I need help fine tuning and balancing the design with your engineering modeling capabilities and expertise.

- Challenge: Field Assembly/Prep
  - I need help with determining a quick pipe field prep method that will increase the friction between the flex hub coupling and pipe
  - The hub coupler will pop off after 5psi without additional surface area contact.
  - Do we just swap all of the pipe clamp bands from screw type to hydraulic bands?
  - Do we leave it as is since it is almost acting as a secondary pressure safety ? >5psi always pops the coupler off- it is startling but not dangerous. Higher PSI = higher risk.
  - Sand the edges of the pipe before putting them into the coupler for texture/grip? Try to fabricate a make-shift bead on the pipe? Add quick-apply skateboard grip tape? Remember – no adhesives requiring lengthy cure times or solvent solutions allowed.

If you have access to other engineers as well, I would like to ensure the design calcs can be cross checked and validated. Last update as well, I have been contacted by one of the Brazilian ventilator contingency planning teams currently looking to support their community with off the shelf solutions, they are eager to see our design when we are complete. At a minimum we can show them sizes and types of parts spec'd out so they can find local equivalents. There will be some very specific items though like the spring types/rates and valve sizes to ensure proper safety venting of the circuit.

Thanks!

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Developing Health in Communities

From: Shane, Cylix
Sent: Saturday, March 21, 2020 10:37 AM
To: 'AK Srouji' <ak@romeopower.com>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; 'Christian Striggow' <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; 'Anthony J Schoen' <aschoen@zagmail.gonzaga.edu>; 'Tony Maiani' <TonyM@mwengineers.com>; 'Eli Goldin' <eli.goldin@inventuspower.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; 'daisy.shane07@gmail.com' <daisy.shane07@gmail.com>; 'Marjorie Thompson' <marjorie0thompson@gmail.com>; Nafzgar, Michael R <Michael.Nafzgar@providence.org>; 'Michael Frank' <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; 'David Paulus' <davidpaulus@hotmail.com>; 'Thompson, Travis' <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; 'zac@additiveamerica.com' <zac@additiveamerica.com>
Subject: RE: [EXTERNAL] Re: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent

Team,
My friend Jason also made a great suggestion for the N/O Valve- we can leverage this with a power supply that will power the timer and be constantly on. Should work as needed. I have ordered the required part for testing. https://www.grainger.com/product/WHITE-RODGERS-Magnetic-Relay-1N184 I will let you know how the tests go.

Thanks

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From: Shane, Cylix
Sent: Saturday, March 21, 2020 9:55 AM
To: AK Srouji <ak@romeopower.com>; Milne, John <John.Milne2@providence.org>; Herr, Alex <Alexander.Herr@providence.org>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Eli Goldin <eli.goldin@inventuspower.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Nafzgar, Michael R <Michael.Nafzgar@providence.org>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; zac@additiveamerica.com
Subject: RE: [EXTERNAL] Re: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent

Team,

One of my cohorts that works for NASA JPL took a look at our design challenge and found this locally sourced timer controller that we can use to control the valves. Made in the USA so no supply chain disruptions, should be easy to program, install and use. Easy to replace. He is looking into our N/O valve

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DAYTON

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Technical Specs

Item - Relay	**Single Function Timing Relay**	Max. Time Setting - Timer	**10 sec.**
Function - Timing Relay	**Repeat Cycle (On First)**	Status Indicator	**None**
Coil Volts	**120VAC/DC**	Contact Material	**Silver Nickel**
AC Contact Rating - Relay	**10A @ 240V**	Body Height - Relay	**2.9"**
DC Contact Rating - Relay	**10A @ 30V**	Body Width - Relay	**2.4"**

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From: Shane, Cylix <Cylix.Shane@providence.org>
Sent: Friday, March 20, 2020 11:40 PM
To: AK Srouji <ak@romeopower.com>
Cc: Milne, John <John.Milne2@providence.org>; Herr, Alex <Alexander.Herr@providence.org>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Eli Goldin <eli.goldin@inventuspower.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Nafzgar, Michael R <Michael.Nafzgar@providence.org>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <David.Thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <Donald.Ruggenberg@providence.org>; zac@additiveamerica.com
Subject: Re: [EXTERNAL] Re: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent

Hi everyone, here is where I am at with the design. Thanks for all of your input and support so far. I will continue refining the timer and normally open solenoid valve. So far we are meeting the program's requirements. Off the shelf, lightweight, affordable, easy to assemble, no adhesives or cure time, adjustable, modular, low tech, no special tools, rapid assembly, common hardware store parts. You've been a great team!

https://youtu.be/X-vWyHA7Vb8

Sent from my Verizon, Samsung Galaxy smartphone
Get Outlook for Android

From: Shane, Cylix
Sent: Friday, March 20, 2020 4:56:18 PM
To: AK Srouji <ak@romeopower.com>
Cc: Milne, John <John.Milne2@providence.org>; Herr, Alex <Alexander.Herr@providence.org>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Eli Goldin <eli.goldin@inventuspower.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com <daisy.shane07@gmail.com>; Marjorie Thompson <marjorie0thompson@gmail.com>; Nafzgar, Michael R <Michael.Nafzgar@providence.org>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <david.thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <donald.ruggenberg@providence.org>; zac@additiveamerica.com <zac@additiveamerica.com>
Subject: RE: [EXTERNAL] Re: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent

Hi Ak,
Those are some pretty good solutions, they are very economical. I will look into ordering a couple for testing. The other alternative I have come across is possibly using a blinker/flasher relay (think of a strobe light controller). Adjustable

blinker relays can be found in most local auto parts stores.
https://www.amazon.com/s?k=adjustable+blinker+relay&ref=nb_sb_noss
Thanks

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From: AK Srouji <ak@romeopower.com>
Sent: Friday, March 20, 2020 2:04 PM
To: Shane, Cylix <Cylix.Shane@providence.org>
Cc: Milne, John <John.Milne2@providence.org>; Herr, Alex <Alexander.Herr@providence.org>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Eli Goldin <eli.goldin@inventuspower.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Nafzgar, Michael R <Michael.Nafzgar@providence.org>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <David.Thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <Donald.Ruggenberg@providence.org>; zac@additiveamerica.com
Subject: [EXTERNAL] Re: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent

Cylix,

pleased to have spoken to you today.

Regarding #1 - albeit recognizing this might not be as off the shelve as you would like:

Idea #1:
There are also multiple simple timers like:
https://www.amazon.com/Qianson-Digital-Display-Infinite-Switch/dp/B01LVXEU3M/ref=pd_bxgy_img_3/146-3253318-7967439?_encoding=UTF8&pd_rd_i=B01LVXEU3M&pd_rd_r=b519fd59-7546-4030-8aaa-8f39a4411d09&pd_rd_w=tKsEV&pd_rd_wg=rqASS&pf_rd_p=1b7ae7c4-8437-4495-a779-460fb30ae641&pf_rd_r=1X3YMM1GG2JM9MZHDHYH&psc=1&refRID=1X3YMM1GG2JM9MZHDHYH
and
https://www.amazon.com/UCTRONICS-Programmable-Multifunction-Segment-Automatic/dp/B07BT32T1M/ref=sr_1_5?keywords=interval+timer+relay&qid=1584724745&sr=8-5
and
https://www.amazon.com/Velleman-VM136-Interval-Timer-Module/dp/B001IRT4ZQ/ref=sr_1_4?keywords=interval+timer+relay&qid=1584724745&sr=8-4

If your colleague was going to manufacture something, a simple timer circuit is easy to build. (I am verifying here if this simple timer circuit can be made with off the shelf components but most likely this is electrical components to be soldered on a board etc...)

Idea #2:

We can create a Phone APP, which will turn on/off the socket through any wireless (Bluetooth or wifi). APP will have the timer to set the time to turn on/off.

- Bluetooth/ WIFI enable power socket
https://www.amazon.com/s?k=bluetooth+socket+plug&i=industrial&crid=1YCFH9BT03Z9I&sprefix=bluetooth+sock%2Cindustrial%2C191&ref=nb_sb_ss_fb_1_14

110V operated - NO Solenoid
https://www.amazon.com/dp/B07JNHGXGS/ref=sspa_dk_detail_3?psc=1&pd_rd_i=B07JNHGXGS&pd_rd_w=Im5L7&pf_rd_p=48d372c1-f7e1-4b8b-9d02-4bd86f5158c5&pd_rd_wg=6QEI0&pf_rd_r=JP9PHBK13YE8W5BYZKEQ&pd_rd_r=9fc27dd3-0af8-4a2c-b0aa-83947dcb2f16&smid=A1X7UA978W3K5N&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEySEpDOVlZS0pGMTdBJmVuY3J5cHRlZElkPUEwOTUwNjA1MURCV1IyUEJCNVNBQyZlbmNyeXB0ZWRBZElkPUEwOTM4NDkxMURaWFY5TEZEUlJVVyZ3aWRnZXROYW1lPXNwX2RldGFpbCZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=

or reverse logic, where when power is always ON which will keep the Solenoid open and power is turned off when Solenoid needs to close.

AK SROUJI, PHD
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On Fri, Mar 20, 2020 at 6:45 AM Shane, Cylix <Cylix.Shane@providence.org> wrote:

> Ok Everyone, we have made great progress this week. Thank you again for volunteering to help me brainstorm some possible solutions. I have hit a speed bump with two of the components to complete the build. This is where I need your help thinking “out of the box” I need your collective brain power- or if you have anyone who you think may be able to come up with a solution for the following 2 components that I am working to reverse engineer to complete the emergency last-resort prototype for testing.
>
> 1. An Electrical or other adjustable way to short-cycle (energize and de-energize) a circuit with a range as low of 2 seconds per cycle, high range of 6 seconds. Remember the challenge is to **only use parts from the common hardware store**. The assembly or modification to any existing device should be quick/relatively simple if possible. The goal is to not waste time when trying to assemble this last resort. This is the closest similar product I have been able to find- the trouble being it is not typically carried by any common US hardware stores but is essentially the function I need to re-create. See the link below, hopefully your creative gears start turning. Here is the closest product commercially available that I was able to find, the challenge again: Must be readily available at a LOCAL hardware store. This is the product we are trying to replicate (with an even shorter cycle range)
> https://www.amazon.com/gp/product/B0184CG9K0/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1

2. A 1” or ¾” air solenoid, or quick acting valve that is **NORMALLY OPEN** when de-energized, this is the last component I need to successfully replicate the PEEP function using only off the shelf hardware. For our HVAC/Pneumatic and flow engineering team members, remember that the valve or diverter required does not have to hold a significant amount of pressure or resistance. The maximum resistance in the line at any time will be less than 50cmH20 (otherwise the air will dump out of the overpressure pop off vent that we made). I thought about using a N/O relay but that wont help when the entire circuit is de-energized it won’t have any energy in the circuit to re-open the typical N/C valve. I need to replicate the N/O feature of this: https://www.electricsolenoidvalves.com/1-inch-24v-dc-electric-solenoid-valve-normally-open/

Those are the two design challenges I need to resolve ASAP to complete the prototype for functional testing.

I have ordered these 2x missing devices that I am using as a guide, they will come in the mail in a few days. I want to take a closer look at their functions and capabilities or show vendors so they can think of solutions as well. Remember all of the mechanical functions can be replicated using alternative means/methods or combinations of parts to accomplish the movement or action required, with the requirement of KEEPING IT SIMPLE. Use your internet crowdsource resources to brainstorm with the online community if you have access to it. Send me your suggestions/potential solutions as soon as possible!

If I can solve for those two variables, the rest of the emergency ventilator can be assembled in minutes, using only a flat head screwdriver, a pair of needle nose pliers, and a sharp object such as a drill bit. See the attached sketch of the current configuration. Please excuse the crude drafting as I do not have the time to formally recreate all of the designs from the off the shelf parts so this is free-hand-eqsue CAD.

Thanks

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Developing Health in Communities
Providence St.Joseph Health

-----Original Appointment-----
From: Shane, Cylix
Sent: Sunday, March 15, 2020 9:42 AM
To: Shane, Cylix; Milne, John; Herr, Alex; Gillespie, Susan M; Bryant, Darrell L; Christian Striggow; Hutchison, Spencer M; Anthony Schoen; Tony Maiani; Imad Idelah; Jeff Downs; Eli Goldin; Kim, Peter H; Martin, Rosemary Y; daisy.shane07@gmail.com
Subject: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent

When: Monday, March 16, 2020 3:00 PM-4:00 PM (UTC-08:00) Pacific Time (US & Canada).
Where: Microsoft Teams Meeting

Team please join me for a kick off and brain storming session. Our main objectives for this meeting will be as follows:
-Introductions
-Brief background, mission focus – why are we doing this
-Define the problem we are trying to solve
-Establish project program, identify key team member roles
-Establish timeline
-Define the goals/milestones that determine project "successful" or not
-Define design problems based off of goals
-Brainstorm possible solutions around the identified constraints
-Establish design parameters, priorities, and assignments.

Please feel free to forward this onto other team members as needed. We have discovered that we are not alone in this effort, the global community is rallying behind the same effort we are to deploy emergency portable vents! We can leverage their lessons learned and input as well. This is quickly gaining momentum across the globe.

https://www.facebook.com/groups/670932227050506/permalink/673493760127686/
https://hackaday.com/2020/03/12/ultimate-medical-hackathon-how-fast-can-we-design-and-deploy-an-open-source-ventilator/
https://app.slack.com/client/TUTSYURT3/CUXD81R6X/user_profile/UV55FG649
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From: Shane, Cylix
Sent: Friday, March 20, 2020 4:56:18 PM
To: AK Srouji <ak@romeopower.com>
Cc: Milne, John <John.Milne2@providence.org>; Herr, Alex <Alexander.Herr@providence.org>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow

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Subject: RE: [EXTERNAL] Re: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent

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https://www.amazon.com/s?k=adjustable+blinker+relay&ref=nb_sb_noss
Thanks

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To: Shane, Cylix <Cylix.Shane@providence.org>
Cc: Milne, John <John.Milne2@providence.org>; Herr, Alex <Alexander.Herr@providence.org>; Gillespie, Susan M <Susan.Gillespie@providence.org>; Bryant, Darrell L <BryantDL@st-lukes.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; Tony Maiani <TonyM@mwengineers.com>; Eli Goldin <eli.goldin@inventuspower.com>; Martin, Rosemary Y <Rosemary.Martin2@providence.org>; daisy.shane07@gmail.com; Marjorie Thompson <marjorie0thompson@gmail.com>; Nafzgar, Michael R <Michael.Nafzgar@providence.org>; Michael Frank <MICHAELF@mckinstry.com>; Hunt, Jason E <Jason.Hunt@providence.org>; Thomsen, David C <David.Thomsen@providence.org>; David Paulus <davidpaulus@hotmail.com>; Thompson, Travis <Travis.Thompson@eu.umicore.com>; Ruggenberg, Donald J <Donald.Ruggenberg@providence.org>; zac@additiveamerica.com
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Cylix,

pleased to have spoken to you today.

Regarding #1 - albeit recognizing this might not be as off the shelve as you would like:

Idea #1:
There are also multiple simple timers like:
https://www.amazon.com/Qianson-Digital-Display-Infinite-Switch/dp/B01LVXEU3M/ref=pd_bxgy_img_3/146-3253318-7967439?_encoding=UTF8&pd_rd_i=B01LVXEU3M&pd_rd_r=b519fd59-7546-4030-8aaa-

8f39a4411d09&pd_rd_w=tKsEV&pd_rd_wg=rqASS&pf_rd_p=1b7ae7c4-8437-4495-a779-460fb30ae641&pf_rd_r=1X3YMM1GG2JM9MZHDHYH&psc=1&refRID=1X3YMM1GG2JM9MZHDHYH
and
https://www.amazon.com/UCTRONICS-Programmable-Multifunction-Segment-Automatic/dp/B07BT32T1M/ref=sr_1_5?keywords=interval+timer+relay&qid=1584724745&sr=8-5
and
https://www.amazon.com/Velleman-VM136-Interval-Timer-Module/dp/B001IRT4ZQ/ref=sr_1_4?keywords=interval+timer+relay&qid=1584724745&sr=8-4

If your colleague was going to manufacture something, a simple timer circuit is easy to build. (I am verifying here if this simple timer circuit can be made with off the shelf components but most likely this is electrical components to be soldered on a board etc...)

Idea #2:

We can create a Phone APP, which will turn on/off the socket through any wireless (Bluetooth or wifi). APP will have the timer to set the time to turn on/off.

- Bluetooth/ WIFI enable power socket
https://www.amazon.com/s?k=bluetooth+socket+plug&i=industrial&crid=1YCFH9BT03Z9I&sprefix=bluetooth+sock%2Cindustrial%2C191&ref=nb_sb_ss_fb_1_14

110V operated - NO Solenoid
https://www.amazon.com/dp/B07JNHGXGS/ref=sspa_dk_detail_3?psc=1&pd_rd_i=B07JNHGXGS&pd_rd_w=Im5L7&pf_rd_p=48d372c1-f7e1-4b8b-9d02-4bd86f5158c5&pd_rd_wg=6QEI0&pf_rd_r=JP9PHBK13YE8W5BYZKEQ&pd_rd_r=9fc27dd3-0af8-4a2c-b0aa-83947dcb2f16&smid=A1X7UA978W3K5N&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEySEpDOVlZS0pGMTdBJmVuY3J5cHRlZElkPUEwOTUwNjA1MURCV1IyUEJCNVNBQyZlbmNyeXB0ZWRBZElkPUEwOTM4NDkxMURaWFY5TEZEUlJVVyZ3aWRnZXROYW1lPXNwX2RldGFpbCZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=

or reverse logic, where when power is always ON which will keep the Solenoid open and power is turned off when Solenoid needs to close.

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On Fri, Mar 20, 2020 at 6:45 AM Shane, Cylix <Cylix.Shane@providence.org> wrote:

> Ok Everyone, we have made great progress this week. Thank you again for volunteering to help me brainstorm some possible solutions. I have hit a speed bump with two of the components to complete the build. This is where I need your help thinking “out of the box” I need your collective brain power- or if you have anyone who you think may be

able to come up with a solution for the following 2 components that I am working to reverse engineer to complete the emergency last-resort prototype for testing.

1. An Electrical or other adjustable way to short-cycle (energize and de-energize) a circuit with a range as low of 2 seconds per cycle, high range of 6 seconds. Remember the challenge is to **only use parts from the common hardware store**. The assembly or modification to any existing device should be quick/relatively simple if possible. The goal is to not waste time when trying to assemble this last resort. This is the closest similar product I have been able to find- the trouble being it is not typically carried by any common US hardware stores but is essentially the function I need to re-create. See the link below, hopefully your creative gears start turning. Here is the closest product commercially available that I was able to find, the challenge again: Must be readily available at a LOCAL hardware store. This is the product we are trying to replicate (with an even shorter cycle range)
   https://www.amazon.com/gp/product/B0184CG9K0/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1

2. A 1" or ¾" air solenoid, or quick acting valve that is **NORMALLY OPEN** when de-energized, this is the last component I need to successfully replicate the PEEP function using only off the shelf hardware. For our HVAC/Pneumatic and flow engineering team members, remember that the valve or diverter required does not have to hold a significant amount of pressure or resistance. The maximum resistance in the line at any time will be less than 50cmH20 (otherwise the air will dump out of the overpressure pop off vent that we made). I thought about using a N/O relay but that wont help when the entire circuit is de-energized it won't have any energy in the circuit to re-open the typical N/C valve. I need to replicate the N/O feature of this:
   https://www.electricsolenoidvalves.com/1-inch-24v-dc-electric-solenoid-valve-normally-open/

Those are the two design challenges I need to resolve ASAP to complete the prototype for functional testing.

I have ordered these 2x missing devices that I am using as a guide, they will come in the mail in a few days. I want to take a closer look at their functions and capabilities or show vendors so they can think of solutions as well. Remember all of the mechanical functions can be replicated using alternative means/methods or combinations of parts to accomplish the movement or action required, with the requirement of KEEPING IT SIMPLE. Use your internet crowdsource resources to brainstorm with the online community if you have access to it. Send me your suggestions/potential solutions as soon as possible!

If I can solve for those two variables, the rest of the emergency ventilator can be assembled in minutes, using only a flat head screwdriver, a pair of needle nose pliers, and a sharp object such as a drill bit. See the attached sketch of the current configuration. Please excuse the crude drafting as I do not have the time to formally recreate all of the designs from the off the shelf parts so this is free-hand-eqsue CAD.

Thanks

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Developing Health in Communities

-----Original Appointment-----
From: Shane, Cylix
Sent: Sunday, March 15, 2020 9:42 AM
To: Shane, Cylix; Milne, John; Herr, Alex; Gillespie, Susan M; Bryant, Darrell L; Christian Striggow; Hutchison, Spencer M; Anthony Schoen; Tony Maiani; Imad Idelah; Jeff Downs; Eli Goldin; Kim, Peter H; Martin, Rosemary Y; daisy.shane07@gmail.com
Subject: Kick off - Emergency Rapid Deploy Battery Powered Ventilator- Ave Maria (AM) Vent
When: Monday, March 16, 2020 3:00 PM-4:00 PM (UTC-08:00) Pacific Time (US & Canada).
Where: Microsoft Teams Meeting

Team please join me for a kick off and brain storming session. Our main objectives for this meeting will be as follows:
-Introductions
-Brief background, mission focus – why are we doing this
-Define the problem we are trying to solve
-Establish project program, identify key team member roles
-Establish timeline
-Define the goals/milestones that determine project "successful" or not
-Define design problems based off of goals
-Brainstorm possible solutions around the identified constraints
-Establish design parameters, priorities, and assignments.

Please feel free to forward this onto other team members as needed. We have discovered that we are not alone in this effort, the global community is rallying behind the same effort we are to deploy emergency portable vents! We can leverage their lessons learned and input as well. This is quickly gaining momentum across the globe.

https://www.facebook.com/groups/670932227050506/permalink/673493760127686/
https://hackaday.com/2020/03/12/ultimate-medical-hackathon-how-fast-can-we-design-and-deploy-an-open-source-ventilator/
https://app.slack.com/client/TUTSYURT3/CUXD81R6X/user_profile/UV55FG649
https://www.facebook.com/groups/670932227050506/?notif_id=1584288015570262&notif_t=group_r2j_approved
https://docs.google.com/document/d/1cM87eJdXhP_8e9gJJZ_SnZXdo_huWsBmMzcqYWbhEOg/preview

---

Join Microsoft Teams Meeting

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571147130@t.plcm.vc VTC Conference ID: 1125701688
Alternate VTC dialing instructions

CORE TEAM DISCUSSION MAIN THREAD

(this has been the main one, there are several break-out discussions)

Shane, Cylix

From: Shane, Cylix
Sent: Saturday, April 11, 2020 9:53 AM
To: Matt Whigham; Christian Striggow
Cc: jamie@m5industries.com; Bryant, Darrell L; Tony Maiani; Hutchison, Spencer M; Matt Landoe; Michael Frank; Zhang, Fan; Anthony J Schoen; goldine@umich.edu; Anthony Schoen; Graham Hawkes
Subject: RE: [EXTERNAL] Re: Ave Maria Parts list

Matt,
That is great feedback, I will look into incorporating the suggestions below. See responses below as well!

Cylix Shane
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Developing Health in Communities

From: Matt Whigham <matthewwhigham@gmail.com>
Sent: Saturday, April 11, 2020 9:08 AM
To: Shane, Cylix <Cylix.Shane@providence.org>
Cc: jamie@m5industries.com; Bryant, Darrell L <BryantDL@st-lukes.org>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: [EXTERNAL] Re: Ave Maria Parts list

Cylix,

Great job on the assembly video!!!

A couple of thoughts I had while watching it:

I would suggest pausing the video before adding each part and showing a screenshot of part number and vendor. This way someone only needs the video to buy and assemble the vent.

It might be a good idea to get some Velcro straps or tape to hold the timer relay to the expansion tube just so it is easier to move and hold together. Maybe it would make sense to put the expansion chamber and inspiratory side solenoid in a wide gutter or something like that to make it easier to mount the timer to it and hold it all together.
Yes the wires and hoses can easily become a tripping hazard or get caught on something and yanked out when in motion. I will look at some ideas to easily organize the wiring.

I was surprised to see the Y oriented with the line going to the patient on a short leg of the Y, I would have thought it would have the single side of the Y going to the patient.
You are correct- I should flip the orientation of the wye, I missed that when assembling it.

When running the vent the pressure seemed to ramp up in 1 second then was down for 2 seconds. Isn't that backwards from what we are shooting for? I thought it should be 2 second expansion chamber pressure ramp up with 1 second dispersion? It would be good to note that is what the pressure profile should look like for people setting up the vent.
The timing is correct on the video, when we tested it this last time on the ASL machine we determined @ 4psi w/ a 1 second inhale (expansion), 2 second exhale (dispersion) we had the appropriate settings for initial use - volume and pressure were acceptable.

We showed venting to ambient. Is that ok to not have an exhale peep valve or we just aren't there with it yet since we are working the exhale viral filter.
I do have the components to do the 5-20 cmh2o for the PEEP using another shorter pipe and running it into the bucket, the resistance from the viral filter (or after the filter) will help with PEEP as well once that is designed. For this setup @Christian Striggow had mentioned some good reasoning behind not worrying about PEEP as much for this device. Christian could you let us know if we should look to keep PEEP off or add some?

For the pipe in the bucket, maybe add a rubber lined pipe clamp as a secondary means of holding the riser in the bucket in one position so it can't be bumped further down.
This is a good idea, I was trying to think of another way to hold the pipe in place through the lid without making it too complicated. I will see what I can come up with, if you guys come across something let me know.

Until we get the exhale viral filter should we show the exhale outlet go into the bucket also on a second riser that isn't as deep in the water to make something functional if we need the 5 cm H2O peep on the exhale. We can note to add the filter on the exhale tube in the meantime.
I also need to mention a one way valve or other sort of back-syphon protection so if a patient spontaneously inhales they won't take in a bunch of water from the bucket. I also did not mention the importance of having the device above the bucket to prevent a gravity back syphon as well.

Great work again to all, it is really neat to be a part of this effort!!!

Thanks,

Matt

On Fri, Apr 10, 2020, 7:39 PM Shane, Cylix <Cylix.Shane@providence.org> wrote:

> Core team,
>
> I have uploaded a draft assembly video- please review it if you have time and let me know what should be changed or improved. This would go in conjunction with the parts diagram and the list of materials. I will start working on an infographic build sheet next.
>
> https://youtu.be/BXNm-YMNpPM
>
> Thanks!

Cylix Shane

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Developing Health in Communities

From: Shane, Cylix
Sent: Thursday, April 09, 2020 11:33 AM
To: jamie@m5industries.com; Bryant, Darrell L <BryantDL@st-lukes.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: RE: Ave Maria Parts list

Core team,

Here is the current parts list. I have associated the part #'s with a diagram so it is easier to visualize what parts go where in the build. If you have time, let me know if you find any cheaper alternatives or if you see any discrepancies. I tried to limit the number of sources for parts and also tried to reduce the number of fittings and bushings. If you see a better part combination please let me know asap so I can adjust the materials list. If we can solve the particulate filter design problem we can provide low resource areas with an alternative to medical supply constraints. Otherwise, any of you should be able to utilize this list and diagram to source all of the necessary components to build your own version of the vent.

Thanks!

Cylix Shane

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Developing Health in Communities

From: Shane, Cylix
Sent: Thursday, April 02, 2020 5:39 AM
To: jamie@m5industries.com; Bryant, Darrell L <BryantDL@st-lukes.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: RE: [EXTERNAL] Alternative vent design in progress

Good morning everyone,

I spent the afternoon looking for off the shelf UV-C bulbs and was not able to find any immediately I found this but it is not typically stocked on site https://www.grainger.com/product/DAYTON-UV-Bulb-2HPD8. I love the idea but I think it may strike out on the off-the-shelf challenge, **however** I want to test that theory! If you have time today, I would like you to help with a sort of "scavenger hunt" try to help me find a UV-C bulb and ballast system that is off the shelf in the 253.7 nm or lower range.

The alternative I still do not want to discount is our own insta-hot system that boils the air or piping to sterilize anything viral at 180f. I can accomplish this with some high resistance nichrome wire in a copper tube or by repurposing a hot water heating element into a small pot or jar and then we can run a copper air line through it. If we want to look at this route again it still qualifies for off-the-shelf, simple, effective, and quick assembly. Bottom line for this concept is finding the safest and quickest way to heat a pipe to greater than 180f internal air temperature. What is the safest and easiest way we can we get there? All while still keeping it simple.

As usual, I am also open to suggestions for review as our goal for this module is to find a quick, **low maintenance, low air flow resistance, low tech way to kill the viral particles**, please keep thinking about creative solutions, or even just a part of a solution and we may be able to solve for "x" together. i.e. you guys were thinking about our highest impact-lowest risk options and this is what we have so far:

1. chemical baths, good idea- but evaporates and requires a certain concentration and contact time to be effective, also highly flammable or can be toxic/corrosive/caustic

2. UV – good idea- but seems hard to source parts in bulk and in rural areas in an emergency, expensive, possible ignition source, possible UV high exposure risk https://www.bbc.com/future/article/20200327-can-you-kill-coronavirus-with-uv-light , https://www.ledsmagazine.com/company-newsfeed/article/14172974/iuva-releases-a-fact-sheet-on-covid19-and-uvcband-disinfection https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5552051/
3. Media filter – good idea but clogs that adds resistance to the line and requires media fabric/material that may be getting used for PPE production (supply chain issue) can get expensive
4. Heated water/boiling air tube– easy to DIY with parts but has heat source/possible ignition source – still viable as off-the-shelf, but needs to be designed w/ safety in mind
5. Ultrasonics – good idea but hard to source parts in bulk and in rural areas in an emergency, very expensive, possible ignition source, not low tech

Open to additional creative concepts that we can troubleshoot as a team, thank you for your time gentlemen!

Thanks

Cylix Shane

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Developing Health in Communities

From: Shane, Cylix
Sent: Wednesday, April 01, 2020 10:01 AM
To: jamie@m5industries.com
Cc: Bryant, Darrell L <BryantDL@st-lukes.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham

Hawkes <graham@subseasystems.com>
Subject: RE: [EXTERNAL] Alternative vent design in progress

I would much rather use LED's if possible- I may even have a few spares here at home that I could wire up to a simple meanwell driver but I think my spectrum may not match the required. I will look for an off the shelf UV LED chipset that has the right wavelength. If you guys find one as well let me know. The second critical component would be a quartz glass shield for the UV system, otherwise it is a very easy configuration to replicate.

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Developing Health in Communities

From: jamie@m5industries.com <jamie@m5industries.com>
Sent: Wednesday, April 01, 2020 9:54 AM
To: Shane, Cylix <Cylix.Shane@providence.org>
Cc: Bryant, Darrell L <BryantDL@st-lukes.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: Re: [EXTERNAL] Alternative vent design in progress

Hi,

Note that the link I sent is referring to LEDs. They use much less energy, are more compact. But whatever works and is more available of course is fine.

Jamie

On Apr 1, 2020, at 9:45 AM, Shane, Cylix <Cylix.Shane@providence.org> wrote:

Hi Jamie,

If we want to utilize UV in the way you are suggesting, there is a few off the shelf solutions I have used in other ventures in life! See here https://www.thepondguy.com/product/aqua-ultraviolet-classic-uv-clarifier/water-gardens-fish-ponds-ultraviolet-clarifiers?p=PPCGOOGA&gclid=CjwKCAjw95D0BRBFEiwAcO1KDF0sAQNTmqTDqEp81uaGmYJz3AmbHKghvN3-2tzrrFKyYXTeVWHcLRoCalkQAvD_BwE, we would need to find the right wattage and swap the bulb out to the correct UV nm wavelength to be effective. But it solves the vessel challenge and UV resistant materials. We would just need to size it correctly. It can even be hooked up via standard NPT connections. I have not tried this application for air, only aquatics so we would need to check a few things regarding effective exposure/contact time.

Thanks!

Cylix Shane

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Developing Health in Communities

From: jamie@m5industries.com <jamie@m5industries.com>
Sent: Wednesday, April 01, 2020 9:40 AM
To: Bryant, Darrell L <BryantDL@st-lukes.org>
Cc: Shane, Cylix <Cylix.Shane@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes

<graham@subseasystems.com>
Subject: Re: [EXTERNAL] Alternative vent design in progress

Hi Everyone.

You need to get some women on this group. Too much nerd testosterone here!

Anyway, thanks for the welcome. Cylix is familiar with my recommendation that this be done more analogue like with a motor, a crank and bellows style thing more

like the MIT attempt. But like with most things there is more than one way to do it. If your stuff works and is practical, great.

As to filtering, I question the use of water, steam, etc. as there are complexities with it that start to tip the balance as to practicality. Have you looked into UV-C?

https://hackaday.io/project/170146-open-source-uvgi-respiratory-mask

No resistance to flow, will kill or disable any microbes going through it. I have a number of scientific papers that document that, although all of them are

around having it in ICUs or other hospital environments and they either turn it on after hours or have it in isolated sections like overhead and blocked off

from people below. Wavelengths of 240-260 are what does the job best. 253.7 to be exact. The source listed above is at 270 or so, so it isn't ideal but should be fine,

and there are probably other sources that are slightly different. They usually have a certain recommended time that they need to be on- like 5 or 15 minutes etc. and there are issues

with areas in a room that the light doesn't get to, but we have a very well defined gate that all air going to the patient has to go through, so it should be easy to

make a 'gauntlet' of UV that nothing will be able to hide in, and so if we can identify that a 1.5" ID tube with a certain wattage of UV in it will sterilize a certain volume of air

in a breath cycle, it might be a good solution.

My thought is that there would be a section of tubing with the light in it that is metal or metal plated, and has baffles or something like the gooseneck on a sink to inhibit

light leakage.

In fact it would be funny if you repurposed the standard goosenecks for a common sink for this. They probably aren't that out of scale for your stuff.

Has to be metal or plated metal because the UV attacks plastic.

The discussion in the link above breaks out the math of a way of determining the

energy and time required to disable the virus. I haven't gone through it or applied it to this application, but it seems to me that air flowing through a hose

with a very reflective metal liner would concentrate the energy. UV reflective paint also works (another study I have documented that painting a room

like an ICU with UV reflective paint made a substantial improvement on sterilization) , and so you could just paint the insides of the gooseneck. Standard

plumbing elbows and such would also make an effective U shaped light trap as well if that was easier.

I've also looked at possible side effects like that UV can create ozone, which would be best to not to inhale, but these wavelengths don't produce it.

There might be other things like this that do not involve filters foreign materials like liquids or disinfectants that have to be dealt with; microwaves or ultrasonics,

or electrostatic or coalescing filters that pull particulates to a copper surface that kills stuff, radiant heat without steam, or even dumping the exhaust outside. UV-C seems to me the most practical, does not require

filter changing, is easy to confine and control.

Jamie

> On Apr 1, 2020, at 8:55 AM, Bryant, Darrell L <BryantDL@st-lukes.org> wrote:
>
> However…. Christian and Spencer… would a liquid water sealed peep valve with alcohol as the liquid work?
>
> <image002.jpg>

From: Bryant, Darrell L
Sent: Wednesday, April 1, 2020 8:52 AM
To: Shane, Cylix; Matt Whigham
Cc: Tony Maiani; Christian Striggow; Hutchison, Spencer M; Matt Landoe; Michael Frank; Zhang, Fan; Anthony J Schoen; goldine@umich.edu; Anthony Schoen; Graham Hawkes; jamie@m5industries.com
Subject: RE: [EXTERNAL] Re: Alternative vent design in progress

I am not sure Cylix…

1) It would need to be cooled back to body temperature before returning to the patient

2) Guarantee that it is 100% virus and pathogen free

3) Ensure there is no rebreathing of CO2 or by-products of boiling

4) Anything that recirculates to the patient would need to be strictly water… you would need to start with sterile water or distilled water. Any additive or preservative can cause more problems with lung deterioration and mucous production. All of which will exacerbate the reasons they need ventilated.

From: Shane, Cylix [mailto:Cylix.Shane@providence.org]
Sent: Wednesday, April 1, 2020 8:15 AM
To: Matt Whigham; Bryant, Darrell L
Cc: Tony Maiani; Christian Striggow; Hutchison, Spencer M; Matt Landoe; Michael Frank; Zhang, Fan; Anthony J Schoen; goldine@umich.edu; Anthony Schoen; Graham Hawkes; jamie@m5industries.com
Subject: RE: [EXTERNAL] Re: Alternative vent design in progress

Could I find a way to regulate the steam since the RT's mentioned we need humidity? Recirc it into the system?

Cylix Shane

Design & Construction Manager | Real Estate Strategy & Operations

105 W. 8th Avenue, Suite 7040 | Spokane, Washington 99204

O: 509.824.1585 C: 760.212.6465

cylix.shane@providence.org

Developing Health in Communities

<image003.png>

From: Matt Whigham <matthewwhigham@gmail.com>
Sent: Wednesday, April 01, 2020 8:13 AM
To: Bryant, Darrell L <BryantDL@st-lukes.org>
Cc: Tony Maiani <TonyM@mwengineers.com>; Shane, Cylix <Cylix.Shane@providence.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>; jamie@m5industries.com
Subject: [EXTERNAL] Re: Alternative vent design in progress

Welcome Jamie!

Thinking about the boiling water bath downstream of the PEEP valved, if we go down that route we should probably include a check valve between the patient and the water bath, and the emergency pop off and the emergency bath to prevent very hot air from inadvertently being returned to the patients respiritory system.

Matt Whigham

On Wed, Apr 1, 2020, 7:54 AM Bryant, Darrell L <BryantDL@st-lukes.org> wrote:

> Good idea. The water seal will capture larger particles a filter will still be necessary to capture the rest.

I love the HEPA bag idea. Totally off the shelf.

From: Tony Maiani [mailto:TonyM@MWEngineers.com]
Sent: Wednesday, April 1, 2020 7:25 AM
To: Shane, Cylix
Cc: Christian Striggow; Bryant, Darrell L; Hutchison, Spencer M; Matt Whigham; Matt Landoe; Michael Frank; Zhang, Fan; Anthony J Schoen; goldine@umich.edu; Anthony Schoen; Graham Hawkes;jamie@m5industries.com
Subject: Re: Alternative vent design in progress

Cylix,

I was just thinking this morning about the inverted trap PEEP device and since the exhale will be going through a water bath it seems to me that this will act as a scrubber to catch and contain any droplets that leave the patient. Wondering if we really still need a filter?

If so, I know that you have the HEPA vacuum cleaners bags. Could you attach the full bag to the discharge hose from the PEEP? Seems easier to use the whole bag For large surface area when air is only traveling out through the bag now.

Tony Maiani

Sent from my iPhone

On Apr 1, 2020, at 5:44 AM, Shane, Cylix <Cylix.Shane@providence.org> wrote:

> Core Team,
>
> Jamie Hyneman has been helping us with some high level concept review and refinement on this “brainstorming” exercise. I figured it would be easier to have him jump on this core-team thread as we

focus on sharing knowledge, continuous improvement, and problem solving.

Jamie, thank you for your time and willingness to look at the some of the design problems we are encountering. This is our core team, the bravest and most selfless engineers and therapists I have been able to rally in short order (along with the recent addition of Graham to join us in the design refinement process yesterday). If you see any potential improvements or items we need to consider, please chime and offer your insight – good or bad, it is all useful because at the core of every comment there is typically a valid concern.

Thanks!

Cylix Shane

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cylix.shane@providence.org

Developing Health in Communities

From: Shane, Cylix
Sent: Tuesday, March 31, 2020 11:10 PM
To: Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Bryant, Darrell L <BryantDL@st-lukes.org>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; Matt Landoe <MattL@atsinlandnw.com>; Tony Maiani <TonyM@MWEngineers.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; 'Anthony Schoen' <AnthonyS@MWEngineers.com>
Cc: Graham Hawkes <graham@subseasystems.com>
Subject: Alternative vent design in progress

Core Team,

Graham Hawkes's team over at HAWX Open Ocean, LLC is looking at a similar DIY approach as an alternative ventilation support device. They are leveraging existing SCUBA technology. I have invited him to collaborate with our team as he has very extensive knowledge in how to keep humans alive, specifically using deep-sea exploration ventilation technology.

Graham,

This is the core design team. We have about 13 other lurkers that have been watching our progress but are not really active. Thanks for volunteering to collaborate. If your team has any ideas about our concept and ways we can improve, please share them. Likewise if you would like our team to look at any of your team's work please let us know. We are all volunteers to support the greater good using the skills we have, hopefully sharing knowledge from our community to yours.

Thanks!

Cylix Shane

Design & Construction Manager | Real Estate Strategy & Operations

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cylix.shane@providence.org

Developing Health in Communities

From: Shane, Cylix
Sent: Tuesday, March 31, 2020 3:25 PM
To: Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Bryant, Darrell L <BryantDL@st-lukes.org>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; Matt Landoe

<MattL@atsinlandnw.com>; Tony Maiani <TonyM@MWEngineers.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>
Subject: RE: [EXTERNAL] RE: Vent Valve/solenoids

Team,

I received and installed the 0 pressure resistance valves today that Matt L found for us (they not too expensive and were from California!). They work FANTASTIC. The 1L test lung appears to fully empty within the 2 second exhale window meaning there should no longer be 50ml of air left in the lungs. I am going to work on getting the water-based manometer, safety blow off, and PEEP valves situated next (should be super simple w/ the new design suggested). Christian, would it be possible to visit you again to test the revisions we made to the design? If this works per the design concept, then we just need to finalize the viral filter design and should be able to start dialing in the settings (mostly regulator/PSI settings).

Thanks!

Cylix Shane

Design & Construction Manager | Real Estate Strategy & Operations

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O: 509.824.1585 C: 760.212.6465

cylix.shane@providence.org

Developing Health in Communities

<image001.png>

From: Shane, Cylix
Sent: Sunday, March 29, 2020 4:58 AM
To: Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Bryant, Darrell L <BryantDL@st-lukes.org>; Hutchison, Spencer M

<Spencer.Hutchison@providence.org>
Subject: FW: [EXTERNAL] RE: Vent Valve/solenoids

Team,

Just giving you a heads up that we are working on a zero resistance circuit (as close as we can, we know there is pipe friction loss and other mechanical dynamics that need to be compensated for). After my conversation with Christian I agree that a higher quality solenoid vs a sprinkler diaphragm would be our best option to observe 0 cmh20/PEEP during expiration. These valves would not necessarily be off-the-shelf, they are made in CA. and if we the prototype works, we can get the designs from the mfg. to have our local teams replicate it. Thanks again for all of your hardwork and input. As soon as the parts come in I will connect them up and see how they perform. I am also still hunting for a better off the shelf hose that will flex less.

Cylix Shane

Design & Construction Manager | Real Estate Strategy & Operations

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cylix.shane@providence.org

Developing Health in Communities

From: Shane, Cylix
Sent: Saturday, March 28, 2020 8:55 AM
To: Matt Landoe <MattL@atsinlandnw.com>; Matt Whigham <matthewwhigham@gmail.com>
Subject: RE: [EXTERNAL] RE: Vent Valve/solenoids

This should be in shortly- I saw the CV rates and did some calcs – we should not have any issues with the flow with any of 1" or below valves. I ordered 1",3/4", and ½" for testing.

Thanks

Cylix Shane

Design & Construction Manager | Real Estate Strategy & Operations

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O: 509.824.1585 C: 760.212.6465

cylix.shane@providence.org

Developing Health in Communities

From: Shane, Cylix
Sent: Saturday, March 28, 2020 8:27 AM
To: Matt Landoe <MattL@atsinlandnw.com>; Matt Whigham <matthewwhigham@gmail.com>
Subject: RE: [EXTERNAL] RE: Vent Valve/solenoids

Hi Matt,

That is a very good find! I will order one for testing. The over sized valve should not matter as the pressure in the circuit will try to stay constant at a very low PSI, we as long as the valve is capable of handling a minimum of 26.25L/min of air volume through it with a pressure as low as 1.97 inches of WC that would meet the spec.

Thanks!

Cylix Shane

Design & Construction Manager | Real Estate Strategy & Operations

105 W. 8th Avenue, Suite 7040 | Spokane, Washington 99204

O: 509.824.1585 C: 760.212.6465

cylix.shane@providence.org

Developing Health in Communities

From: Matt Landoe <MattL@atsinlandnw.com>
Sent: Saturday, March 28, 2020 8:21 AM
To: Matt Whigham <matthewwhigham@gmail.com>; Shane, Cylix <Cylix.Shane@providence.org>
Subject: [EXTERNAL] RE: Vent Valve/solenoids

Hi Cylix and Matt,

I think I found a great valve solution. This may be a Chinese valve assembled in America but it is in stock and readily available from California. It is 1.25 inches NPT, Plastic, Normally Closed, with a 24 VAC power requirement. The valve can handle zero differential, handles air and inert gas and it has a very high flow rate. This means you wont need to play with the plunger or anything like that. You probably have smaller hoses so this oversized valve should have a Cv larger than the hose which means its restriction is negligible. It is only available normally closed when deenergized.

You may be able to get by with a ¾ to 1" valve to achieve the correct flow rate (do not know the actual inlet pressure) but this should work in any circumstance. It is less than $95 dollars which is incredible. I don't know if there is any sanitary problem with a plastic valve. I am guessing that there are

other items in the gas train that have similar sanitary issues.

See the link below.

Feel free to call at 509-981-0886.

No feedback yet from Dwyer but great conversation with them. I attached my email to them below as well.

2PCG Series 1.25" Inch Plastic Electric Solenoid Valve Specification:

Model Number: 2PCG-1 1/4-D

Valve Type: 2 Way Normally Closed (Valve opens with energized)

Service Media: Air, Gas, Liquid, Water, Vacuum

Operation Model: Direct Lift Diaphragm

Body Material: PA66 Plastic Valve Body

Seal Material: NBR (Buna N) Diaphragm & Plunger Tip

Coil Power: DC: 30-40W, AC: 35VA

Coil Class: H Class IP 65

Coil Duty: 100% ED (Continuous Duty)

Operating Pressure: Vacuum 0 PSI to 90 PSI

Operating Temperature: 0 to 50 °C or 32 to 122 °F

Port Size: 1.25" Inch NPT Female Port

Coil Voltage Option: 12V DC, 24V DC, 24V AC, 110V AC, 220V AC

Voltage Tolerances: DC: +10% –5% ; AC: +10% -15%

Electrical Connection: DIN 43650A Connector with LED Indicator

https://www.wicvalve.com/125-Inch-Plastic-Zero-Differential-Electric-Solenoid-Valve-2PCG-1-1-4-D.htm

Email to Dwyer:

Hi David,

I am an HVAC controls customer of yours. We are an Alerton dealer in Spokane. One of our customers is Providence Medical. They are a large health care organization, the largest in Washington state.

They are trying to deal with the COVID 19 emergency and expect to seriously run out of ventilators. They are assembling a volunteer team of doctors and specialists to be able to create a reliable off the self solution that will be easy to build in quantity.

I have selected a number of components to build a 4th generation prototype. They got to gen 3 successfully with timers and remote instrumentation. I am suggesting they really improve their pressure control and line up with readily available hardware.

If you were able to sample some items it would be greatly appreciated. They are talking about quickly building hundreds of these but frankly it could also go nowhere if someone invents some quick easy cheap solution.

For me, I think there are lives at stake and if we could be proactive, our efforts would not be wasted.

If you could sample these items I would be extremely grateful!

We are not selling them anything. We are just introducing them to proper sources as volunteers.

Here are the parts:

- (1) MS2-W103 Pressure sensor (ideal) (OR)
- (1) 616KD-B-06 pressure transmitter
- (1) BDPA-07-2-N Pressure Hi Limit with buzzer (OR)
- (1) ADPS-07-2N
- (1) 16L2034 Limit Controller
- (1) Ratemaster RMA-13-TMV (OR)
- (1) VFB-60-SSV

David, these guys are running against the clock. I really appreciate anything you can do.

Feel free to call with questions.

Thanks, Matt

From: Matt Landoe
Sent: Friday, March 27, 2020 2:16 PM
To: Matt Whigham <matthewwhigham@gmail.com>; Shane, Cylix <Cylix.Shane@providence.org>
Subject: RE: Vent Valve/solenoids

Hi Matt,

Good to talk with you and it is great what you are trying to accomplish.<

Viral Filter Discussion

Shane, Cylix

From: Shane, Cylix
Sent: Friday, April 03, 2020 5:05 AM
To: 'jamie@m5industries.com'; Bryant, Darrell L; 'Matt Whigham'; 'Tony Maiani'; 'Christian Striggow'; Hutchison, Spencer M; 'Matt Landoe'; 'Michael Frank'; Zhang, Fan; 'Anthony J Schoen'; 'goldine@umich.edu'; 'Anthony Schoen'; 'Graham Hawkes'
Subject: RE: [EXTERNAL] Alternative vent design in progress
Attachments: WSU Viral Filtration design challenge.docx

Team,
Just a heads up that I have reached out to one of my cohorts at WSU to see if we can turn the viral filter into a "Hack-a-Thon" college challenge. He was very excited about the idea and is going to circulate the attached. Please let me know if you see any major concerns. I broke out the viral particle module separate from the overall vent brainstorming effort to keep the students focused on refining one part of the whole and to prevent them from trying to "boil the ocean". Looking forward to testing the updated prototype and reviewing the new Percussionaire ventilators with everyone today.

Thanks!

Cylix Shane
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cylix.shane@providence.org
Developing Health in Communities
Providence St.Joseph Health

From: Shane, Cylix
Sent: Thursday, April 02, 2020 5:39 AM
To: jamie@m5industries.com; Bryant, Darrell L <BryantDL@st-lukes.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: RE: [EXTERNAL] Alternative vent design in progress

Good morning everyone,
I spent the afternoon looking for off the shelf UV-C bulbs and was not able to find any immediately I found this but it is not typically stocked on site https://www.grainger.com/product/DAYTON-UV-Bulb-2HPD8. I love the idea but I think it may strike out on the off-the-shelf challenge, **however** I want to test that theory! If you have time today, I would like you to help with a sort of "scavenger hunt" try to help me find a UV-C bulb and ballast system that is off the shelf in the 253.7 nm or lower range.

The alternative I still do not want to discount is our own insta-hot system that boils the air or piping to sterilize anything viral at 180f. I can accomplish this with some high resistance nichrome wire in a copper tube or by repurposing a hot water heating element into a small pot or jar and then we can run a copper air line through it. If we want to look at this route again it still qualifies for off-the-shelf, simple, effective, and quick assembly. Bottom line for this concept is finding

the safest and quickest way to heat a pipe to greater than 180f internal air temperature. What is the safest and easiest way we can we get there? All while still keeping it simple.

As usual, I am also open to suggestions for review as our goal for this module is to find a quick, **low maintenance, low air flow resistance, low tech way to kill the viral particles**, please keep thinking about creative solutions, or even just a part of a solution and we may be able to solve for "x" together. i.e. you guys were thinking about our highest impact-lowest risk options and this is what we have so far:

1. chemical baths, good idea- but evaporates and requires a certain concentration and contact time to be effective, also highly flammable or can be toxic/corrosive/caustic
2. UV – good idea- but seems hard to source parts in bulk and in rural areas in an emergency, expensive, possible ignition source, possible UV high exposure risk https://www.bbc.com/future/article/20200327-can-you-kill-coronavirus-with-uv-light , https://www.ledsmagazine.com/company-newsfeed/article/14172974/iuva-releases-a-fact-sheet-on-covid19-and-uvcband-disinfection https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5552051/
3. Media filter – good idea but clogs that adds resistance to the line and requires media fabric/material that may be getting used for PPE production (supply chain issue) can get expensive
4. Heated water/boiling air tube– easy to DIY with parts but has heat source/possible ignition source – still viable as off-the-shelf, but needs to be designed w/ safety in mind
5. Ultrasonics – good idea but hard to source parts in bulk and in rural areas in an emergency, very expensive, possible ignition source, not low tech

Open to additional creative concepts that we can troubleshoot as a team, thank you for your time gentlemen!

Thanks

Cylix Shane
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O: 509.824.1585 C: 760.212.6465
cylix.shane@providence.org
Developing Health in Communities
Providence St.Joseph Health

From: Shane, Cylix
Sent: Wednesday, April 01, 2020 10:01 AM
To: jamie@m5industries.com
Cc: Bryant, Darrell L <BryantDL@st-lukes.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: RE: [EXTERNAL] Alternative vent design in progress

I would much rather use LED's if possible- I may even have a few spares here at home that I could wire up to a simple meanwell driver but I think my spectrum may not match the required. I will look for an off the shelf UV LED chipset that has the right wavelength. If you guys find one as well let me know. The second critical component would be a quartz glass shield for the UV system, otherwise it is a very easy configuration to replicate.

Cylix Shane
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cylix.shane@providence.org
Developing Health in Communities

From: jamie@m5industries.com <jamie@m5industries.com>
Sent: Wednesday, April 01, 2020 9:54 AM
To: Shane, Cylix <Cylix.Shane@providence.org>
Cc: Bryant, Darrell L <BryantDL@st-lukes.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: Re: [EXTERNAL] Alternative vent design in progress

Hi,

Note that the link I sent is referring to LEDs. They use much less energy, are more compact. But whatever works and is more available of course is fine.

Jamie

> On Apr 1, 2020, at 9:45 AM, Shane, Cylix <Cylix.Shane@providence.org> wrote:
>
> Hi Jamie,
> If we want to utilize UV in the way you are suggesting, there is a few off the shelf solutions I have used in other ventures in life! See here https://www.thepondguy.com/product/aqua-ultraviolet-classic-uv-clarifier/water-gardens-fish-ponds-ultraviolet-clarifiers?p=PPCGOOGA&gclid=CjwKCAjw95D0BRBFEiwAcO1KDF0sAQNTmqTDqEp81uaGmYJz3AmbHKghvN3-2tzrrFKyYXTeVWHcLRoCalkQAvD_BwE, we would need to find the right wattage and swap the bulb out to the correct UV nm wavelength to be effective. But it solves the vessel challenge and UV resistant materials. We would just need to size it correctly. It can even be hooked up via standard NPT connections. I have not tried this application for air, only aquatics so we would need to check a few things regarding effective exposure/contact time.
>
> Thanks!
>
> Cylix Shane
> Design & Construction Manager | Real Estate Strategy & Operations
> 105 W. 8th Avenue, Suite 7040 | Spokane, Washington 99204
> O: 509.824.1585 C: 760.212.6465
> cylix.shane@providence.org
> Developing Health in Communities
> <image001.png>

From: jamie@m5industries.com <jamie@m5industries.com>
Sent: Wednesday, April 01, 2020 9:40 AM
To: Bryant, Darrell L <BryantDL@st-lukes.org>
Cc: Shane, Cylix <Cylix.Shane@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; Tony Maiani <TonyM@mwengineers.com>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>
Subject: Re: [EXTERNAL] Alternative vent design in progress

Hi Everyone.
You need to get some women on this group. Too much nerd testosterone here!

Anyway, thanks for the welcome. Cylix is familiar with my recommendation that this be done more analogue like with a motor, a crank and bellows style thing more
like the MIT attempt. But like with most things there is more than one way to do it. If your stuff works and is practical, great.

As to filtering, I question the use of water, steam, etc. as there are complexities with it that start to tip the balance as to practicality. Have you looked into UV-C?
https://hackaday.io/project/170146-open-source-uvgi-respiratory-mask

No resistance to flow, will kill or disable any microbes going through it. I have a number of scientific papers that document that, although all of them are
around having it in ICUs or other hospital environments and they either turn it on after hours or have it in isolated sections like overhead and blocked off
from people below. Wavelengths of 240-260 are what does the job best. 253.7 to be exact. The source listed above is at 270 or so, so it isn't ideal but should be fine,
and there are probably other sources that are slightly different. They usually have a certain recommended time that they need to be on- like 5 or 15 minutes etc. and there are issues
with areas in a room that the light doesn't get to, but we have a very well defined gate that all air going to the patient has to go through, so it should be easy to
make a 'gauntlet' of UV that nothing will be able to hide in, and so if we can identify that a 1.5" ID tube with a certain wattage of UV in it will sterilize a certain volume of air
in a breath cycle, it might be a good solution.
My thought is that there would be a section of tubing with the light in it that is metal or metal plated, and has baffles or something like the gooseneck on a sink to inhibit
light leakage.
In fact it would be funny if you repurposed the standard goosenecks for a common sink for this. They probably aren't that out of scale for your stuff.
Has to be metal or plated metal because the UV attacks plastic.

The discussion in the link above breaks out the math of a way of determining the
energy and time required to disable the virus. I haven't gone through it or applied it to this application, but it seems to me that air flowing through a hose
with a very reflective metal liner would concentrate the energy. UV reflective paint also works (another study I have documented that painting a room
like an ICU with UV reflective paint made a substantial improvement on sterilization) , and so you could just paint the insides of the gooseneck. Standard
plumbing elbows and such would also make an effective U shaped light trap as well if that was easier.

I've also looked at possible side effects like that UV can create ozone, which would be best to not to inhale, but these wavelengths don't produce it.
There might be other things like this that do not involve filters foreign materials like liquids or disinfectants that have to be dealt with; microwaves or ultrasonics,
or electrostatic or coalescing filters that pull particulates to a copper surface that kills stuff, radiant heat without steam, or even dumping the exhaust outside. UV-C seems to me the most practical, does not require
filter changing, is easy to confine and control.

Jamie

On Apr 1, 2020, at 8:55 AM, Bryant, Darrell L <BryantDL@st-lukes.org> wrote:

However…. Christian and Spencer… would a liquid water sealed peep valve with alcohol as the liquid work?

<image002.jpg>

From: Bryant, Darrell L
Sent: Wednesday, April 1, 2020 8:52 AM
To: Shane, Cylix; Matt Whigham
Cc: Tony Maiani; Christian Striggow; Hutchison, Spencer M; Matt Landoe; Michael Frank; Zhang, Fan; Anthony J Schoen; goldine@umich.edu; Anthony Schoen; Graham Hawkes; jamie@m5industries.com
Subject: RE: [EXTERNAL] Re: Alternative vent design in progress

I am not sure Cylix…

1) It would need to be cooled back to body temperature before returning to the patient
2) Guarantee that it is 100% virus and pathogen free
3) Ensure there is no rebreathing of CO2 or by-products of boiling
4) Anything that recirculates to the patient would need to be strictly water… you would need to start with sterile water or distilled water. Any additive or preservative can cause more problems with lung deterioration and mucous production. All of which will exacerbate the reasons they need ventilated.

From: Shane, Cylix [mailto:Cylix.Shane@providence.org]
Sent: Wednesday, April 1, 2020 8:15 AM
To: Matt Whigham; Bryant, Darrell L
Cc: Tony Maiani; Christian Striggow; Hutchison, Spencer M; Matt Landoe; Michael Frank; Zhang, Fan; Anthony J Schoen; goldine@umich.edu; Anthony Schoen; Graham Hawkes; jamie@m5industries.com
Subject: RE: [EXTERNAL] Re: Alternative vent design in progress

Could I find a way to regulate the steam since the RT's mentioned we need humidity? Recirc it into the system?

Cylix Shane
Design & Construction Manager | Real Estate Strategy & Operations
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O: 509.824.1585 C: 760.212.6465
cylix.shane@providence.org
Developing Health in Communities
<image003.png>

From: Matt Whigham <matthewwhigham@gmail.com>
Sent: Wednesday, April 01, 2020 8:13 AM
To: Bryant, Darrell L <BryantDL@st-lukes.org>
Cc: Tony Maiani <TonyM@mwengineers.com>; Shane, Cylix <Cylix.Shane@providence.org>; Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Landoe <MattL@atsinlandnw.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; Anthony Schoen <AnthonyS@mwengineers.com>; Graham Hawkes <graham@subseasystems.com>; jamie@m5industries.com
Subject: [EXTERNAL] Re: Alternative vent design in progress

Welcome Jamie!

Thinking about the boiling water bath downstream of the PEEP valved, if we go down that route we should probably include a check valve between the patient and the water bath, and the emergency pop off and the emergency bath to prevent very hot air from inadvertently being returned to the patients respiritory system.

Matt Whigham

On Wed, Apr 1, 2020, 7:54 AM Bryant, Darrell L <BryantDL@st-lukes.org> wrote:

> Good idea. The water seal will capture larger particles a filter will still be necessary to capture the rest.
>
> I love the HEPA bag idea. Totally off the shelf.
>
> ---
>
> **From:** Tony Maiani [mailto:TonyM@MWEngineers.com]
> **Sent:** Wednesday, April 1, 2020 7:25 AM
> **To:** Shane, Cylix
> **Cc:** Christian Striggow; Bryant, Darrell L; Hutchison, Spencer M; Matt Whigham; Matt Landoe; Michael Frank; Zhang, Fan; Anthony J Schoen; goldine@umich.edu; Anthony Schoen; Graham Hawkes;jamie@m5industries.com
> **Subject:** Re: Alternative vent design in progress
>
> Cylix,
>
> I was just thinking this morning about the inverted trap PEEP device and since the exhale will be going through a water bath it seems to me that this will act as a scrubber

to catch and contain any droplets that leave the patient. Wondering if we really still need a filter?

If so, I know that you have the HEPA vacuum cleaners bags. Could you attach the full bag to the discharge hose from the PEEP? Seems easier to use the whole bag For large surface area when air is only traveling out through the bag now.

Tony Maiani
Sent from my iPhone

On Apr 1, 2020, at 5:44 AM, Shane, Cylix <Cylix.Shane@providence.org> wrote:

> Core Team,
> Jamie Hyneman has been helping us with some high level concept review and refinement on this "brainstorming" exercise. I figured it would be easier to have him jump on this core-team thread as we focus on sharing knowledge, continuous improvement, and problem solving.
>
> Jamie, thank you for your time and willingness to look at the some of the design problems we are encountering. This is our core team, the bravest and most selfless engineers and therapists I have been able to rally in short order (along with the recent addition of Graham to join us in the design refinement process yesterday). If you see any potential improvements or items we need to consider, please chime and offer your insight – good or bad, it is all useful because at the core of every comment there is typically a valid concern.
>
> Thanks!

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From: Shane, Cylix
Sent: Tuesday, March 31, 2020 11:10 PM
To: Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Bryant, Darrell L <BryantDL@st-lukes.org>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; Matt Landoe <MattL@atsinlandnw.com>; Tony Maiani <TonyM@MWEngineers.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>; goldine@umich.edu; 'Anthony

Schoen' <AnthonyS@MWEngineers.com>
Cc: Graham Hawkes <graham@subseasystems.com>
Subject: Alternative vent design in progress

Core Team,
Graham Hawkes's team over at HAWX Open Ocean, LLC is looking at a similar DIY approach as an alternative ventilation support device. They are leveraging existing SCUBA technology. I have invited him to collaborate with our team as he has very extensive knowledge in how to keep humans alive, specifically using deep-sea exploration ventilation technology.

Graham,
This is the core design team. We have about 13 other lurkers that have been watching our progress but are not really active. Thanks for volunteering to collaborate. If your team has any ideas about our concept and ways we can improve, please share them. Likewise if you would like our team to look at any of your team's work please let us know. We are all volunteers to support the greater good using the skills we have, hopefully sharing knowledge from our community to yours.

Thanks!
Cylix Shane
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cylix.shane@providence.org
Developing Health in Communities
<image001.png>

From: Shane, Cylix
Sent: Tuesday, March 31, 2020 3:25 PM
To: Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Bryant, Darrell L <BryantDL@st-lukes.org>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>; Matt Whigham <matthewwhigham@gmail.com>; Matt Landoe <MattL@atsinlandnw.com>; Tony Maiani <TonyM@MWEngineers.com>; Michael Frank <MICHAELF@mckinstry.com>; Zhang, Fan <Fan.Zhang@providence.org>; Anthony J Schoen <aschoen@zagmail.gonzaga.edu>
Subject: RE: [EXTERNAL] RE: Vent Valve/solenoids

Team,
I received and installed the 0 pressure resistance valves today that Matt L found for us (they not too expensive and were from California!). They work FANTASTIC. The 1L test lung appears to fully empty within the 2 second exhale window meaning there should no longer be 50ml of air left in the lungs. I am going to work on getting the water-based manometer, safety blow off, and PEEP valves situated next (should be

super simple w/ the new design suggested). Christian, would it be possible to visit you again to test the revisions we made to the design? If this works per the design concept, then we just need to finalize the viral filter design and should be able to start dialing in the settings (mostly regulator/PSI settings).

Thanks!

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Developing Health in Communities
<image001.png>

From: Shane, Cylix
Sent: Sunday, March 29, 2020 4:58 AM
To: Christian Striggow <Christian.STRIGGOW@scc.spokane.edu>; Bryant, Darrell L <BryantDL@st-lukes.org>; Hutchison, Spencer M <Spencer.Hutchison@providence.org>
Subject: FW: [EXTERNAL] RE: Vent Valve/solenoids

Team,
Just giving you a heads up that we are working on a zero resistance circuit (as close as we can, we know there is pipe friction loss and other mechanical dynamics that need to be compensated for). After my conversation with Christian I agree that a higher quality solenoid vs a sprinkler diaphragm would be our best option to observe 0 cmh20/PEEP during expiration. These valves would not necessarily be off-the-shelf, they are made in CA. and if we the prototype works, we can get the designs from the mfg. to have our local teams replicate it. Thanks again for all of your hardwork and input. As soon as the parts come in I will connect them up and see how they perform. I am also still hunting for a better off the shelf hose that will flex less.

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<image001.png>

From: Shane, Cylix
Sent: Saturday, March 28, 2020 8:55 AM
To: Matt Landoe <MattL@atsinlandnw.com>; Matt Whigham <matthewwhigham@gmail.com>
Subject: RE: [EXTERNAL] RE: Vent Valve/solenoids

This should be in shortly- I saw the CV rates and did some calcs – we should not have any issues with the flow with any of 1" or below valves. I ordered 1",3/4", and ½" for testing.
Thanks

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<image001.png>

From: Shane, Cylix
Sent: Saturday, March 28, 2020 8:27 AM
To: Matt Landoe <MattL@atsinlandnw.com>; Matt Whigham <matthewwhigham@gmail.com>
Subject: RE: [EXTERNAL] RE: Vent Valve/solenoids

Hi Matt,
That is a very good find! I will order one for testing. The over sized valve should not matter as the pressure in the circuit will try to stay constant at a very low PSI, we as long as the valve is capable of handling a minimum of 26.25L/min of air volume through it with a pressure as low as 1.97 inches of WC that would meet the spec.
Thanks!

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<image001.png>

From: Matt Landoe <MattL@atsinlandnw.com>
Sent: Saturday, March 28, 2020 8:21 AM
To: Matt Whigham <matthewwhigham@gmail.com>; Shane, Cylix <Cylix.Shane@providence.org>
Subject: [EXTERNAL] RE: Vent Valve/solenoids

Hi Cylix and Matt,

I think I found a great valve solution. This may be a Chinese valve assembled in America but it is in stock and readily available from California. It is 1.25 inches

NPT, Plastic, Normally Closed, with a 24 VAC power requirement. The valve can handle zero differential, handles air and inert gas and it has a very high flow rate. This means you wont need to play with the plunger or anything like that. You probably have smaller hoses so this oversized valve should have a Cv larger than the hose which means its restriction is negligible. It is only available normally closed when deenergized.

You may be able to get by with a ¾ to 1" valve to achieve the correct flow rate (do not know the actual inlet pressure) but this should work in any circumstance. It is less than $95 dollars which is incredible. I don't know if there is any sanitary problem with a plastic valve. I am guessing that there are other items in the gas train that have similar sanitary issues.

See the link below.

Feel free to call at 509-981-0886.

No feedback yet from Dwyer but great conversation with them. I attached my email to them below as well.

2PCG Series 1.25" Inch Plastic Electric Solenoid Valve Specification:

Model Number: 2PCG-1 1/4-D

Valve Type: 2 Way Normally Closed (Valve opens with energized)

Service Media: Air, Gas, Liquid, Water, Vacuum

Operation Model: Direct Lift Diaphragm

Body Material: PA66 Plastic Valve Body

Seal Material: NBR (Buna N) Diaphragm & Plunger Tip

Coil Power: DC: 30-40W, AC: 35VA

Coil Class: H Class IP 65

Coil Duty: 100% ED (Continuous Duty)

Operating Pressure: Vacuum 0 PSI to 90 PSI

Operating Temperature: 0 to 50 °C or 32 to 122 °F

Port Size: 1.25" Inch NPT Female Port

Coil Voltage Option: 12V DC, 24V DC, 24V AC, 110V AC, 220V AC

Voltage Tolerances: DC: +10% –5% ; AC: +10% -15%

Electrical Connection: DIN 43650A Connector with LED Indicator

https://www.wicvalve.com/125-Inch-Plastic-Zero-Differential-Electric-Solenoid-Valve-2PCG-1-1-4-D.htm

Email to Dwyer:

Hi David,
I am an HVAC controls customer of yours. We are an Alerton dealer in Spokane. One of our customers is Providence Medical. They are a large health care organization, the largest in Washington state.
They are trying to deal with the COVID 19 emergency and expect to seriously run out of ventilators. They are assembling a volunteer team of doctors and specialists to be able to create a reliable off the self solution that will be easy to build in quantity.
I have selected a number of components to build a 4th generation prototype. They got to gen 3 successfully with timers and remote instrumentation. I am suggesting they really improve their pressure control and line up with readily available hardware.
If you were able to sample some items it would be greatly appreciated. They are talking about quickly building hundreds of these but frankly it could also go nowhere if someone invents some quick easy cheap solution.
For me, I think there are lives at stake and if we could be proactive, our efforts would not be wasted.
If you could sample these items I would be extremely grateful!

We are not selling them anything. We are just introducing them to proper sources as volunteers.
Here are the parts:

- (1) MS2-W103 Pressure sensor (ideal) (OR)
- (1) 616KD-B-06 pressure transmitter
- (1) BDPA-07-2-N Pressure Hi Limit with buzzer (OR)
- (1) ADPS-07-2N
- (1) 16L2034 Limit Controller
- (1) Ratemaster RMA-13-TMV (OR)
- (1) VFB-60-SSV

David, these guys are running against the clock. I really appreciate anything you can do.
Feel free to call with questions.
Thanks, Matt

From: Matt Landoe
Sent: Friday, March 27, 2020 2:16 PM
To: Matt Whigham <matthewwhigham@gmail.com>; Shane, Cylix <Cylix.Shane@providence.org>
Subject: RE: Vent Valve/solenoids

Hi Matt,

Good to talk with you and it is great what you are trying to accomplish.

Forgive my lack of response.

I am a one armed paper hanger this week and I am buried with people wanting to start “critical” projects!

I am thinking that the relief valve can easily be achieved through the use of a diaphragm shuttle valve that is pneumatically operated by a separate small electric pilot valve. When the diaphragm opens the valve is really high capacity and releases fast. However most have a bleed port that leaks air. They are used for baghouse filter cleaning in explosion proof environments.

I just haven't located a diaphragm valve that isn't a quick exhaust valve. I don't like the bleed port. Still need to do more research. Also some have a minimum pressure requirement.

Thanks, Matt

From: Matt Whigham <matthewwhigham@gmail.com>
Sent: Friday, March 27, 2020 1:23 PM
To: Shane, Cylix <Cylix.Shane@providence.org>
Cc: Matt Landoe <MattL@atsinlandnw.com>
Subject: Re: Vent Valve/solenoids

Nice to digitally meet you Matt!

Any thoughts on solenoid or controller selection?

On Fri, Mar 27, 2020, 12:03 PM Shane, Cylix <Cylix.Shane@providence.org> wrote:

> Hi Matt,
> Here is what we are looking at- trying to get zero resistance on the exhaust side and enough flow capacity to allow 750ml of air out in 1 second. Matt Whigham is my cohort that has been helping me track down a good solenoid/valve.
>
> Matt W., meet Matt L., Matt L. from ATS is an expert in controls, automation, gasses, and a vast wealth of knowledge overall, he has volunteered to take a second look at some of our sensors, controls, and valve options.
>
> We need a "none required" pressure drop across the valve.
>
> 1/4inch DC 12V 2 Way Normally Closed Electric Solenoid Air Valve https://www.amazon.com/dp/B084YTNG2P/ref=cm_sw_r_em_apa_i_zCyFEbJ52AXQG
> here is another one https://www.amazon.com/Way-Position-Solenoid-Valve-Wired/dp/B00FJ5FGH8#feature-bullets-btf
> https://www.grainger.com/product/REDHAT-12VDC-Brass-Solenoid-Valve-6WTT7 12 V normally closed rated for air 0 - 130 psi
>
> Thanks!
>
> Cylix Shane
> Design & Construction Manager | Real Estate Strategy & Operations
> 105 W. 8th Avenue, Suite 7040 | Spokane, Washington 99204
> O: 509.824.1585 C: 760.212.6465
> cylix.shane@providence.org

From: Shane, Cylix <Cylix.Shane@providence.org>
Sent: Thursday, March 26, 2020 9:07 PM
To: Matt Whigham <matthewwhigham@gmail.com>
Subject: Re: FW: [EXTERNAL] Fwd: email to Adam Savage

That's more of what I'm thinking should work optimally.

Sent from my Verizon, Samsung Galaxy smartphone
Get Outlook for Android

From: Matt Whigham <matthewwhigham@gmail.com>
Sent: Thursday, March 26, 2020 9:03:33 PM
To: Shane, Cylix <Cylix.Shane@providence.org>
Subject: Re: FW: [EXTERNAL] Fwd: email to Adam Savage

here is another one https://www.amazon.com/Way-Position-Solenoid-Valve-Wired/dp/B00FJ5FGH8#feature-bullets-btf

On Thu, Mar 26, 2020 at 9:02 PM Matt Whigham <matthewwhigham@gmail.com> wrote:

> awesome you got an email back from him!
>
> here is a solenoid valve that would work!
>
> https://www.grainger.com/product/REDHAT-12VDC-Brass-Solenoid-Valve-6WTT7 12 V normally closed rated for air 0 - 130 psi

This message is intended for the sole use of the addressee, and may contain information that is privileged, confidential and exempt from disclosure under applicable law. If you are not the addressee you are hereby notified that you may not use, copy, disclose, or distribute to anyone the message or any information contained in the message. If you have received this message in error, please immediately advise the sender by reply email and delete this message.

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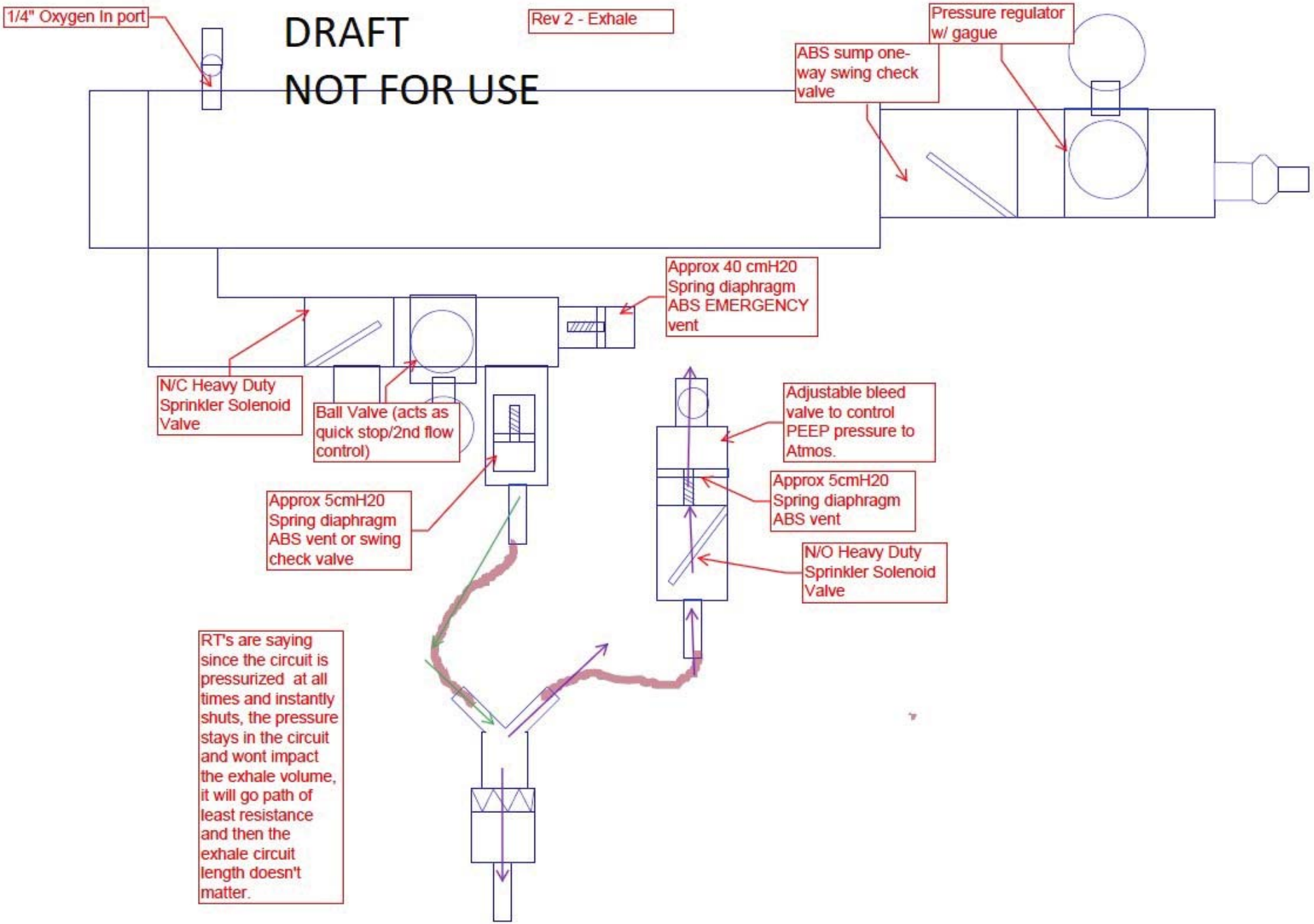
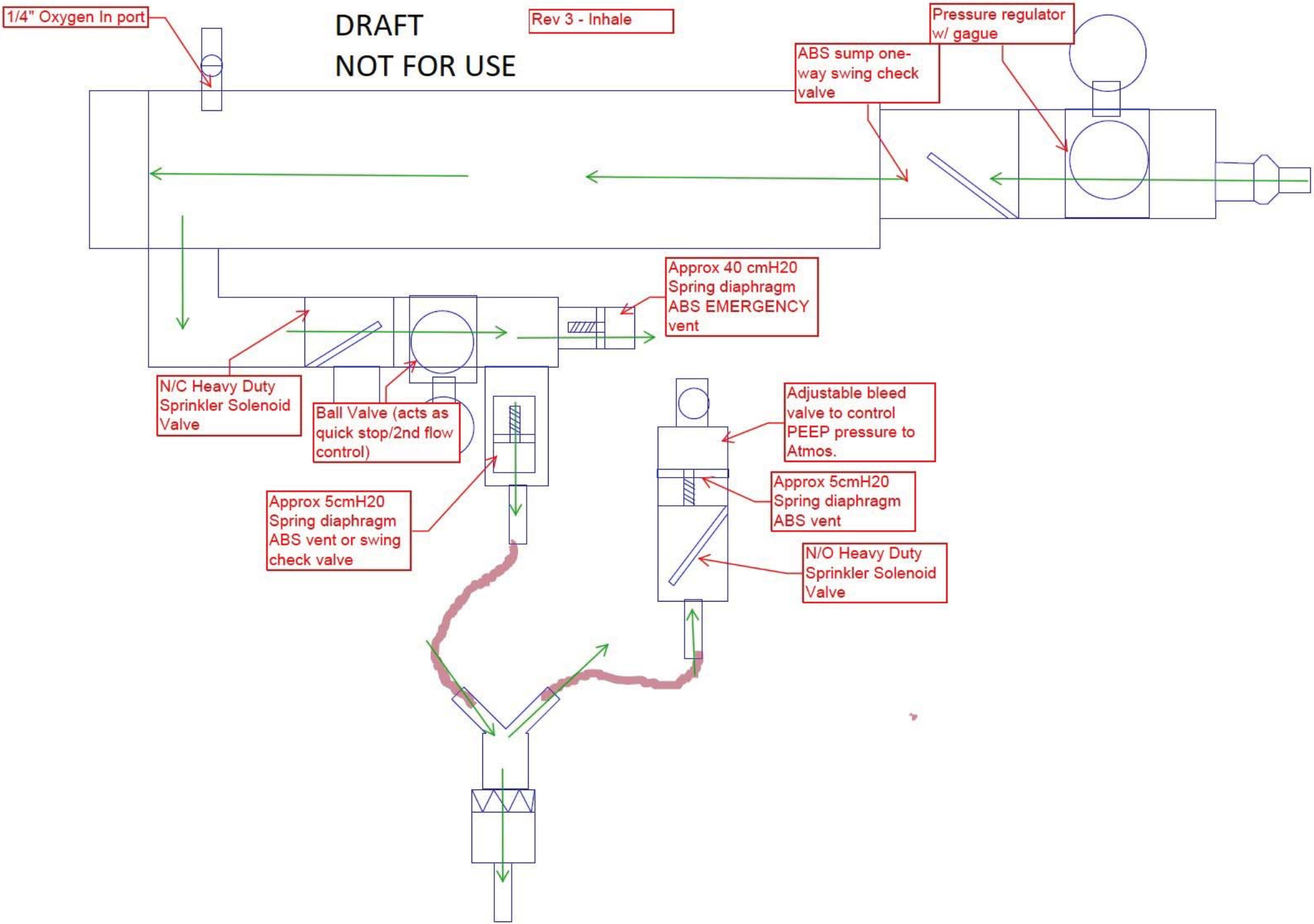
Concept Development 5th revision


1/4" Oxygen In port
DRAFT
NOT FOR USE
Rev 2 - Exhale
Pressure regulator w/ gague
ABS sump one-way swing check valve
Approx 40 cmH20 Spring diaphragm ABS EMERGENCY vent
N/C Heavy Duty Sprinkler Solenoid Valve
Ball Valve (acts as quick stop/2nd flow control)
Adjustable bleed valve to control PEEP pressure to Atmos.
Approx 5cmH20 Spring diaphragm ABS vent
Approx 5cmH20 Spring diaphragm ABS vent or swing check valve
N/O Heavy Duty Sprinkler Solenoid Valve
RT's are saying since the circuit is pressurized at all times and instantly shuts, the pressure stays in the circuit and wont impact the exhale volume, it will go path of least resistance and then the exhale circuit length doesn't matter.


1/4" Oxygen In port
DRAFT
NOT FOR USE
Rev 3 - Inhale
Pressure regulator w/ gague
ABS sump one-way swing check valve
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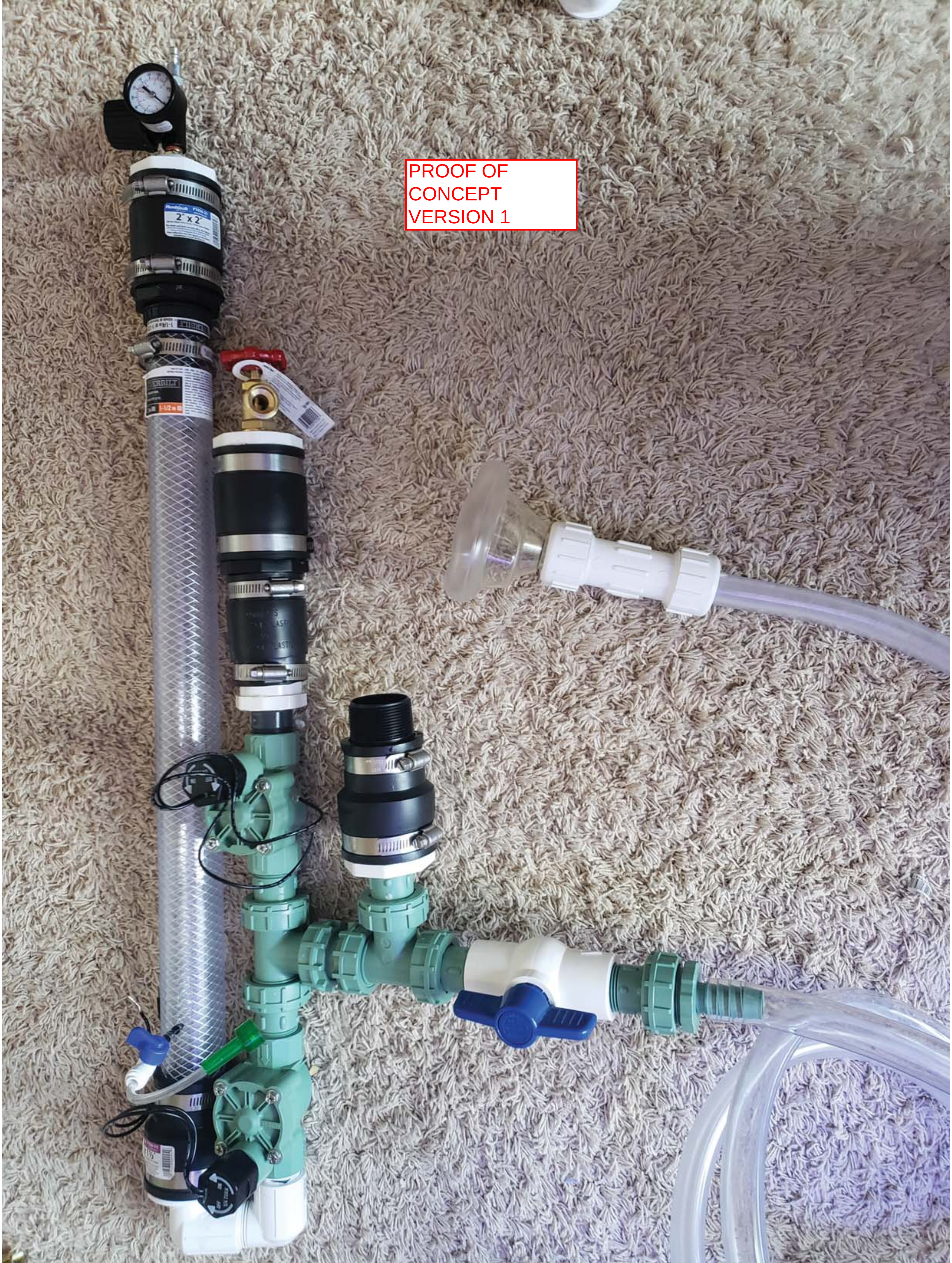
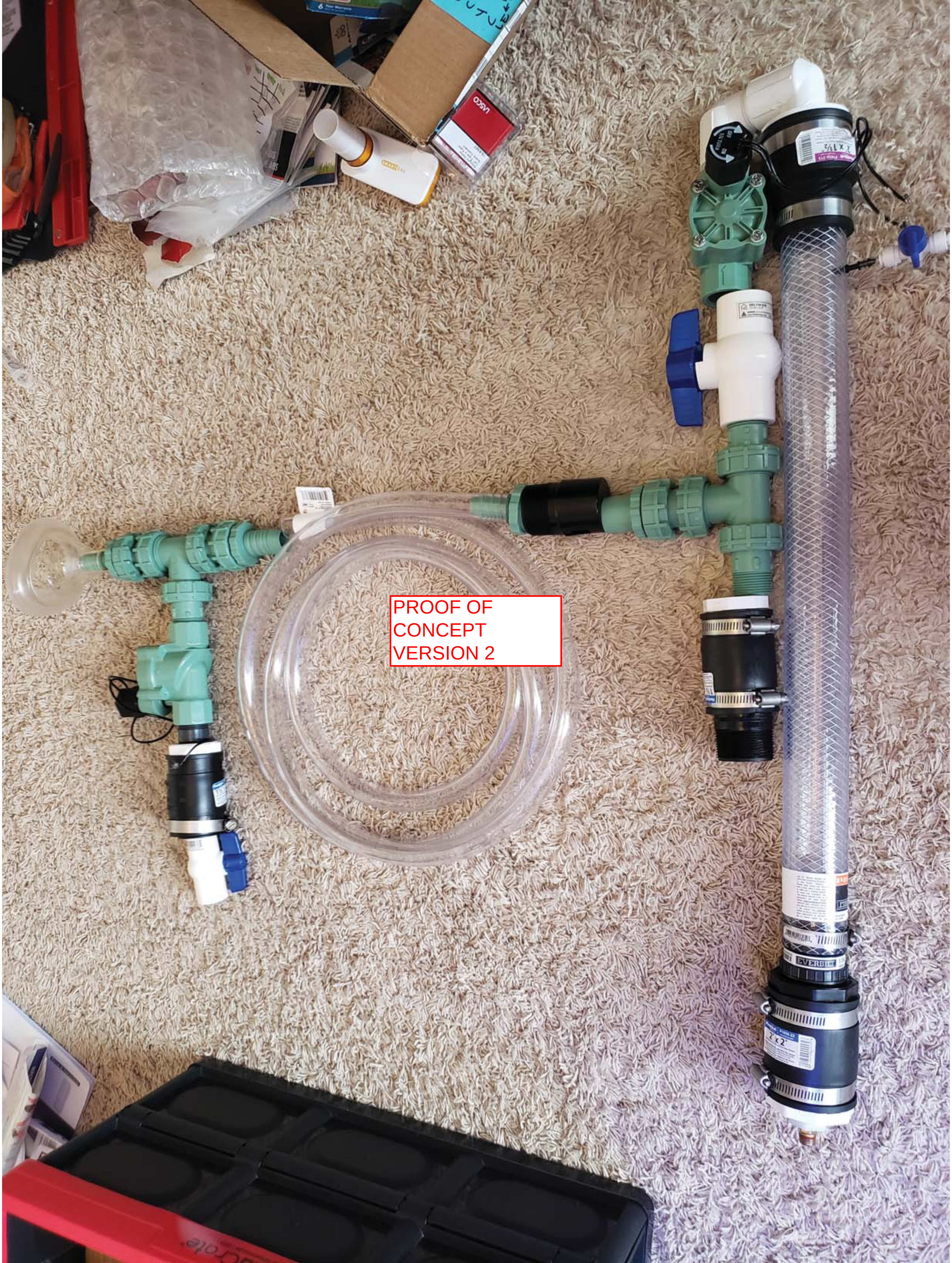
N/C Heavy Duty Sprinkler Solenoid Valve
Ball Valve (acts as quick stop/2nd flow control)
Adjustable bleed valve to control PEEP pressure to Atmos.
Approx 5cmH20 Spring diaphragm ABS vent
Approx 5cmH20 Spring diaphragm ABS vent or swing check valve
N/O Heavy Duty Sprinkler Solenoid Valve


PROOF OF
CONCEPT
VERSION 1


PROOF OF
CONCEPT
VERSION 2
EVERBILT

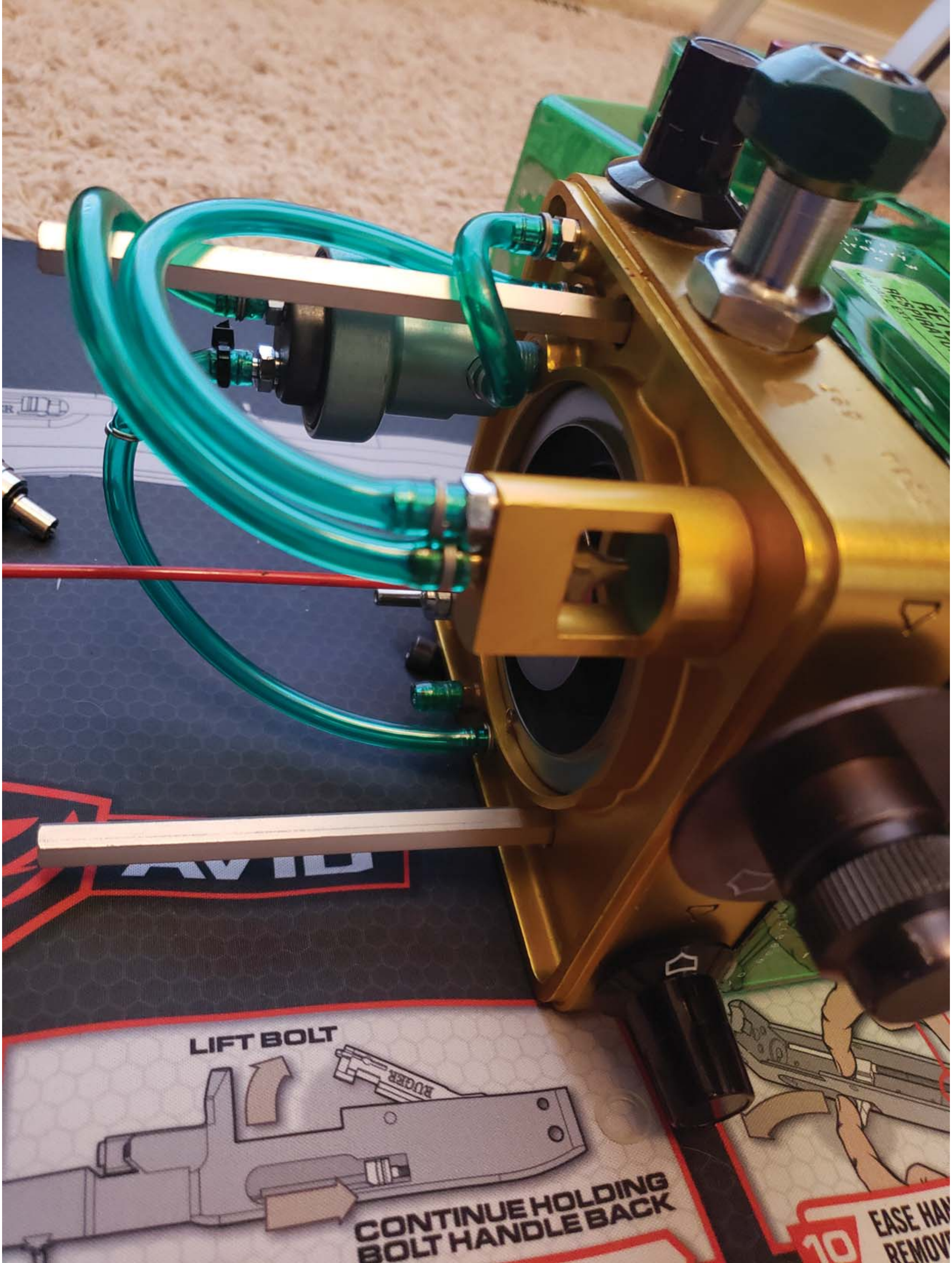

PROOF OF
CONCEPT DIY
PEEP AND
Emergency Vent

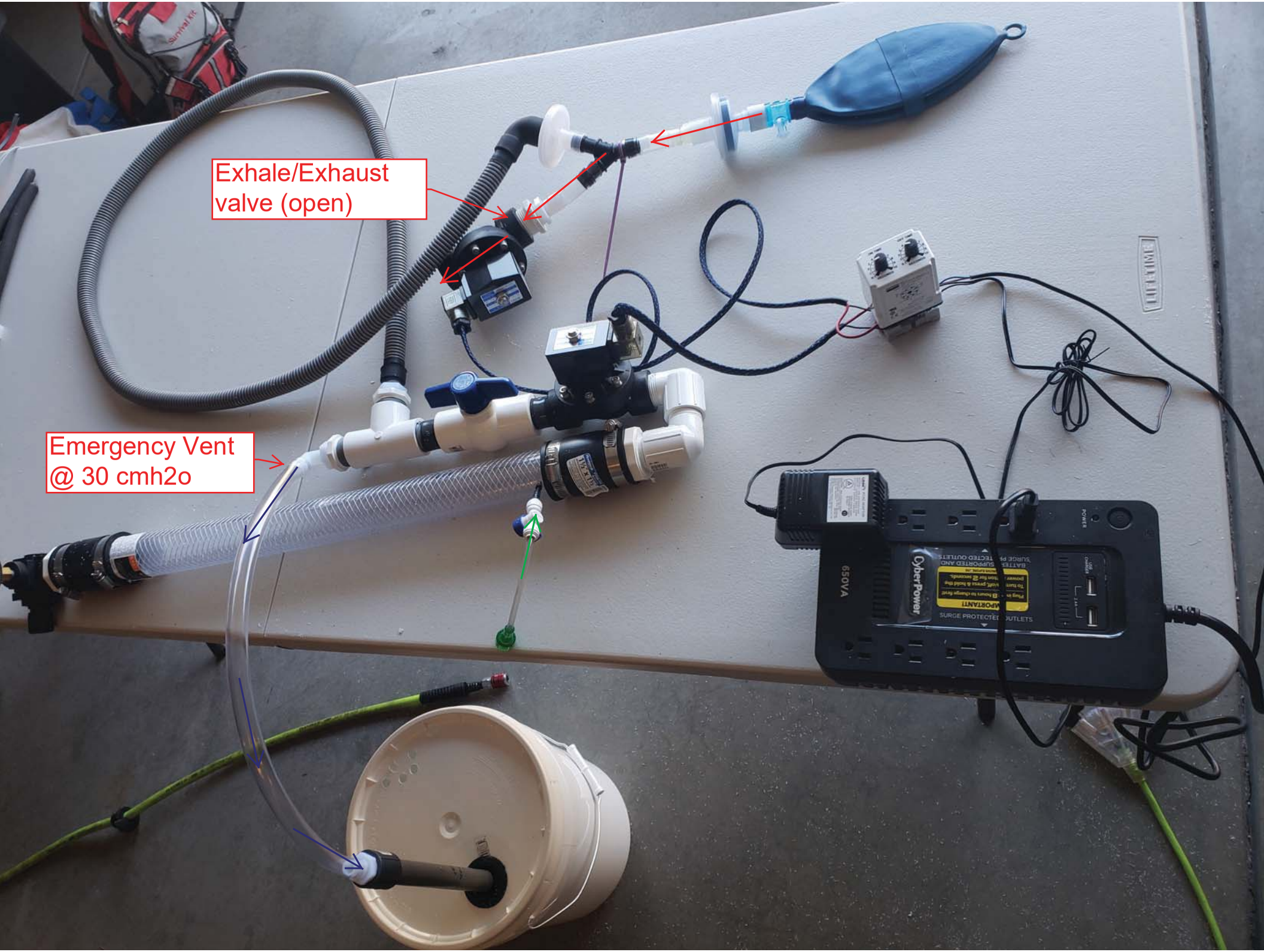

PROOF OF
CONCEPT R3

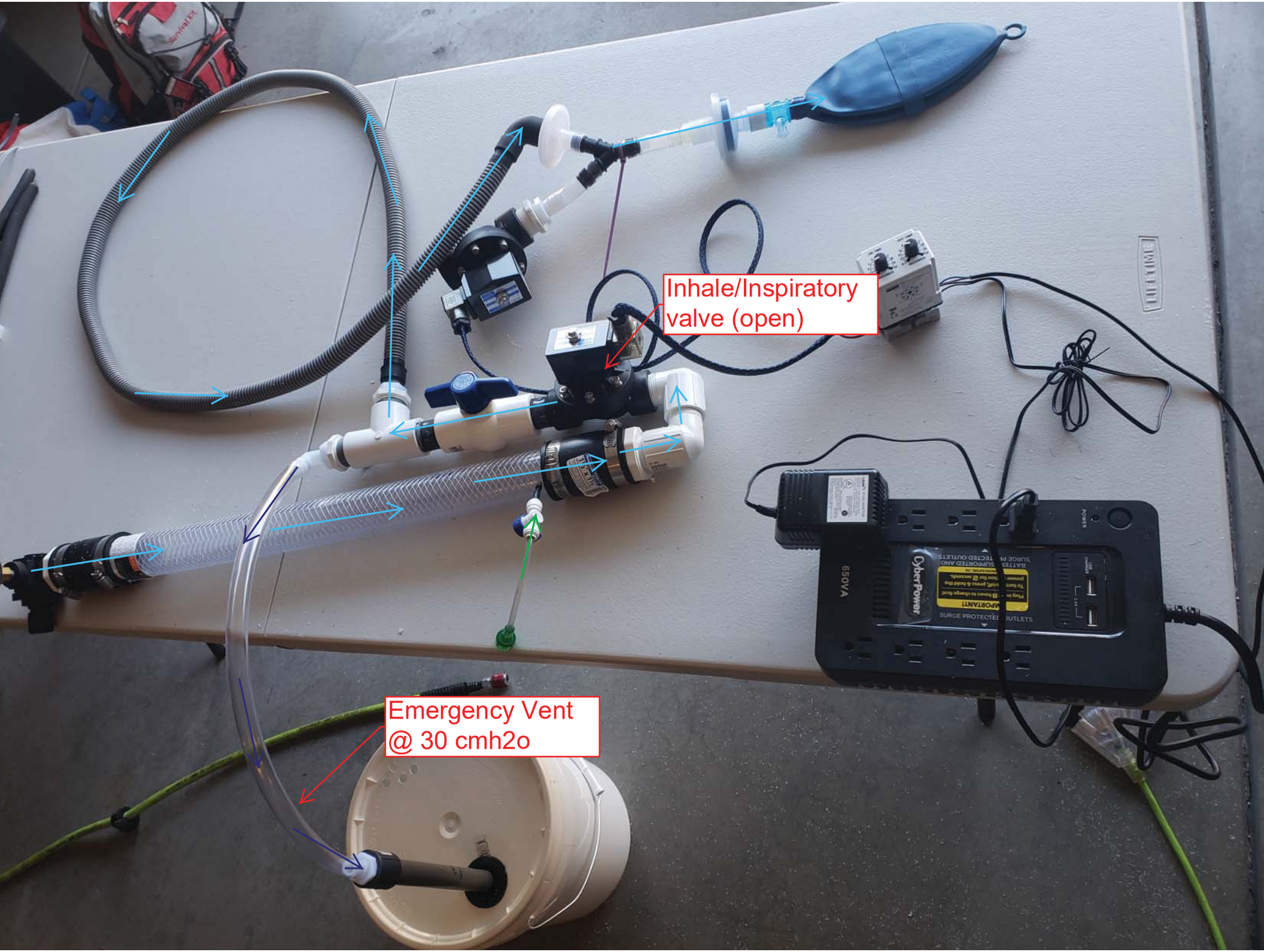

PROOF OF
CONCEPT R5
CyberPower
650VA


Percussionaire pneumatic vent for reference
bird
MARK 14
positive phase
ventilator
palm springs
california
u s a
MILLIMETERS OF MERCURY
POSITIVE PRESSURE
NEGATIVE PRESSURE
initial
inspiratory
f l o w
controlled
expiratory
t i m e


PRESSURE
P15
R10
RETURN TO
RESPIRATORY CARE
U.S. patents:
3088856 3172405 3688794
3234932 3638636 3739776
Patented in other countries.
CONTINUE HOLDING
BOLT HANDLE BACK
CONTINUE HOLDING HANDLE
LIFT BOLT FROM RECEIVER
NOTE THAT
SPRING TIP
MUST REST
IN DIMPLE
DURING
REASSEMBLY
10
EASE HANDLE FORWARD,
REMOVE THROUGH PORT
RUGER AND 10/22 ARE TRADEMARK
TO RUGER 10/22 FIREARMS AND


LIFT BOLT
RUGER
CONTINUE HOLDING
BOLT HANDLE BACK
AVID
10


Exhale/Exhaust valve (open)
Emergency Vent @ 30 cmh2o
CyberPower
650VA


Inhale/Inspiratory valve (open)
Emergency Vent @ 30 cmh2o
CyberPower
650VA

Ave Maria Parts List

Date Prepared: **4/4/20**

CYLIX CONCEPTS & DESIGNS

Item #	MFG Part #	Description	Cost	Qty	Total	Link
PARTS FROM GRAINGER						
1	14H03M	GUARDAIR Air Compressor Steel Universal Quick Coupler Plug 1/4" MNTP	$3.89	1	$3.89	https://www.grainger.com/product/GUARDAIR-Steel-Universal-Quick-Coupler-3KVL2
2	R37121-100	ARO 1/4" General Purpose Air Regulator , 59 cfm Max. Flow - Regulators	$33.75	1	$33.75	https://www.grainger.com/product/ARO-1-4-General-Purpose-Air-Regulator-4PJG6
3	18C775	Grainger Pressure Gauge, 0 to 10 psi Range, 1/4" NPT, ±1.50% Gauge Accuracy	$58.00	1	$58.00	https://www.grainger.com/product/GRAINGER-APPROVED-Pressure-Gauge-18C775
4	VS222P-4-2	PARKER Brass Reducing Adapter, FNPT x MNPT, 1/4" x 1/8" Pipe Size, 1 EA	$2.81	1	$2.81	https://www.grainger.com/product/PARKER-Brass-Reducing-Adapter-13Y819
5	706122-04	Grainger Brass Hex Nipple, MNPT, 1/4" Pipe Size, 1 EA	$1.82	1	$1.82	https://www.grainger.com/product/GRAINGER-APPROVED-Brass-Hex-Nipple-46M442
6	839-128	GF Piping PVC Reducing Bushing, MNPT x FNPT, 1" x 1/4" Pipe Size - Pipe Fitting	$7.10	1	$7.10	https://www.grainger.com/product/GF-PIPING-SYSTEMS-PVC-Reducing-Bushing-6MV66
7	E1420-10	NDS Ball Valve, PVC, 2-Way, 1-Piece, Pipe Size 1", Tube Size 1", Connection Type FNPT x FNPT	$5.76	1	$5.76	https://www.grainger.com/product/NDS-Ball-Valve-54XJ79
8	861-134	Grainger Nipple, Threaded on Both Ends, Pipe Nipple, Pipe Schedule 80, Pipe Size - Nominal 1"	$1.52	3	$4.56	https://www.grainger.com/product/GRAINGER-APPROVED-Nipple-6MW06
9	405010	LASCO PVC Tee, FNPT x FNPT x FNPT, 1" Pipe Size - Pipe Fitting	$3.22	1	$3.22	https://www.grainger.com/product/LASCO-PVC-Tee-22FK97
10	5X852	DAYTON Relay Socket, Socket Type: Standard, Socket Style: Octal, Number of Pins: 8	$11.40	1	$11.40	https://www.grainger.com/product/DAYTON-Relay-Socket-5X852
11	3MRP3	Grainger Style 1 Rubber Grommet, 1" I.D., 1-3/4" O.D., 1/8" Panel Thickness, PK10	$13.30	1	$13.30	https://www.grainger.com/product/GRAINGER-APPROVED-Style-1-Rubber-Grommet-3MRP3
12	1EGD1	DAYTON Single Function Timing Relay, 120VAC/DC, 10A @ 240V, 8 Pins, DPDT	$66.00	1	$66.00	https://www.grainger.com/product/DAYTON-Single-Function-Timing-Relay-1EGD1
PARTS FROM ACE HARDWARE						
13	19-9725	Nylon Barb Fitting, 5/8X3/4-Inch , Insert X Male Pipe, 90 Degree Elbow, Use With I.D. Size Poly Tubing, Carded	$6.00	1	$6.00	http://www.lasco.net/nylon-male-90deg-elbow-c-741_960_968/cd-plst-34mip-x-58-ell-p-10805
14	19-9679	LASCO CD PLST 3/4MIP X 5/8 ADAPTOR	$6.00	3	$18.00	http://www.lasco.net/nylon-male-adapter-c-741_960_967/cd-plst-34mip-x-58-adaptor-p-10755
15	1AP-005-006FBK	Ace 18/2 SPT-2 125 volt 6 ft. L Appliance Cord	$5.99	1	$5.99	https://www.acehardware.com/departments/lighting-and-electrical/extension-cords-and-power-strips/power-cords/31460
16	57040	Orbit 2 zone Sprinkler Timer Transformer	$18.99	1	$18.99	https://www.acehardware.com/departments/lawn-and-garden/watering-and-irrigation/sprinkler-timers/7191547
PARTS FROM HOME DEPOT						
17	P1056-150	Fernco 1-1/2 in. x 1-1/2 in. DWV Flexible PVC Coupling	$4.10	1	$4.10	https://www.homedepot.com/p/Fernco-1-1-2-in-x-1-1-2-in-DWV-Flexible-PVC-Coupling-P1056-150/100058870
18	PVC02108 1800HD	Charlotte Pipe 1-1/2 in. x 1 in. PVC Sch. 40 Spigot x FPT Reducer Bushing	$1.14	2	$2.28	https://www.homedepot.com/p/Charlotte-Pipe-1-1-2-in-x-1-in-PVC-Sch-40-Spigot-x-FPT-Reducer-Bushing-PVC021081800HD/203811594
19	PVC 02112 2000HD	Charlotte Pipe 1 in. x 3/4 in. PVC Sch. 40 Reducer Bushing	$1.44	3	$4.32	https://www.homedepot.com/p/Charlotte-Pipe-1-in-x-3-4-in-PVC-Sch-40-Reducer-Bushing-PVC-02112-2000HD/203850938
20	HKP002-PVC009	EVERBILT 2 in. O.D. x 1-1/2 in. I.D. x 24 in. Clear PVC Braided Vinyl Tubing	$6.91	1	$6.91	https://www.homedepot.com/p/Everbilt-2-in-O-D-x-1-1-2-in-I-D-x-24-in-Clear-PVC-Braided-Vinyl-Tubing-HKP002-PVC009/303132533
21	PVC023071000HD	Charlotte Pipe 1 in. PVC Sch. 40 90-Degree MPT x FPT Street Elbow	$2.17	2	$4.34	https://www.homedepot.com/p/Charlotte-Pipe-1-in-PVC-Sch-40-90-Degree-MPT-x-FPT-Street-Elbow-PVC023071000HD/204837327
22	PVC081021200HA	Charlotte Pipe 3/4 in. PVC FPT x FPT Coupling	$5.91	1	$5.91	https://www.homedepot.com/p/Charlotte-Pipe-3-4-in-PVC-FPT-x-FPT-Coupling-PVC081021200HA/202268523
23	38166D	3/4 in. x 24 in. PVC Riser	$2.38	1	$2.38	https://www.homedepot.com/p/3-4-in-x-24-in-PVC-Riser-38166D/100131226
24	49910325	Southwire 25 ft. 18/2 Black Stranded CU SPT-1 Lamp Wire	$4.24	1	$4.24	https://www.homedepot.com/p/Southwire-25-ft-18-2-Black-Stranded-CU-SPT-1-Lamp-Wire-49910325/301827862
25	702554	EVERBILT 3/4 in. O.D. x 5/8 in. I.D. x 10 ft. Clear PVC Vinyl Tubing	$9.84	1	$9.84	https://www.homedepot.com/p/Everbilt-3-4-in-O-D-x-5-8-in-I-D-x-10-ft-Clear-PVC-Vinyl-Tubing-702554/207144269
26	HRBDIS06EB	EVERBILT 6 ft. Corrugated Dishwasher Hose	$11.98	1	$11.98	https://www.homedepot.com/p/Everbilt-6-ft-Corrugated-Dishwasher-Hose-HRBDIS06EB/206578686
27	209325	LeakTite White Reusable Easy Off Lid for 5-Gal. Pail	$5.97	1	$5.97	https://www.homedepot.com/p/Leaktite-White-Reusable-Easy-Off-Lid-for-5-Gal-Pail-Pack-of-3-209325/203925466
28	005GFSWH020	Leaktite 5 gal. 70mil Food Safe Bucket White	$4.76	1	$4.76	https://www.homedepot.com/p/Leaktite-5-gal-70mil-Food-Safe-Bucket-White-005GFSWH020/300197644
29	800399	EVERBILT 5/8 in. I.D. Plastic Hose Barb Tee Fitting	$3.74	1	$3.74	https://www.homedepot.com/p/Everbilt-5-8-in-I-D-Plastic-Hose-Barb-Tee-Fitting-800399/300862713
30	701906	1/4 in. O.D. x 1/6 in. I.D. x 10 ft. Clear PVC Vinyl Tubing	$2.96	1	$2.96	https://www.homedepot.com/p/Everbilt-1-4-in-O-D-x-1-6-in-I-D-x-10-ft-Clear-PVC-Vinyl-Tubing-701906/207144203
31	803189	John Guest 1/4 in. O.D. Polypropylene Push-to-Connect Valve	$10.36	1	$10.36	https://www.homedepot.com/p/John-Guest-1-4-in-O-D-Polypropylene-Push-to-Connect-Valve-803189/300753479
32	H80A	DIG 1/4 in. Barb Connectors (10-Pack)	$1.67	1	$1.67	https://www.homedepot.com/p/DIG-1-4-in-Barb-Connectors-10-Pack-H80A/100114529
33	306212	OATEY Fastape 1/2 in. x 260 in. PTFE Thread Seal Tape	$3.30	1	$3.30	https://www.homedepot.com/p/Oatey-Fastape-1-2-in-x-260-in-PTFE-Thread-Seal-Tape-306212/203529858
PARTS FROM WIC VALVES						
34	2PCG-1	WIC 1" Inch PA66 Plastic Zero Differential Electric Solenoid Valve	$51.61	2	$103.22	https://www.wicvalve.com/searchquick-submit.sc?keywords=2PCG-1-D
PARTS FROM CPAP						
35	BF2200	CPAP Final Bacteria Filter 15mm/22mm Disc	$4.00	1	$4.00	https://www.cpap-supply.com/Sunset-Bacteria-Filter-Single-p/bf2200-single.htm
			EACH UNIT	**Total**	**$456.87**	

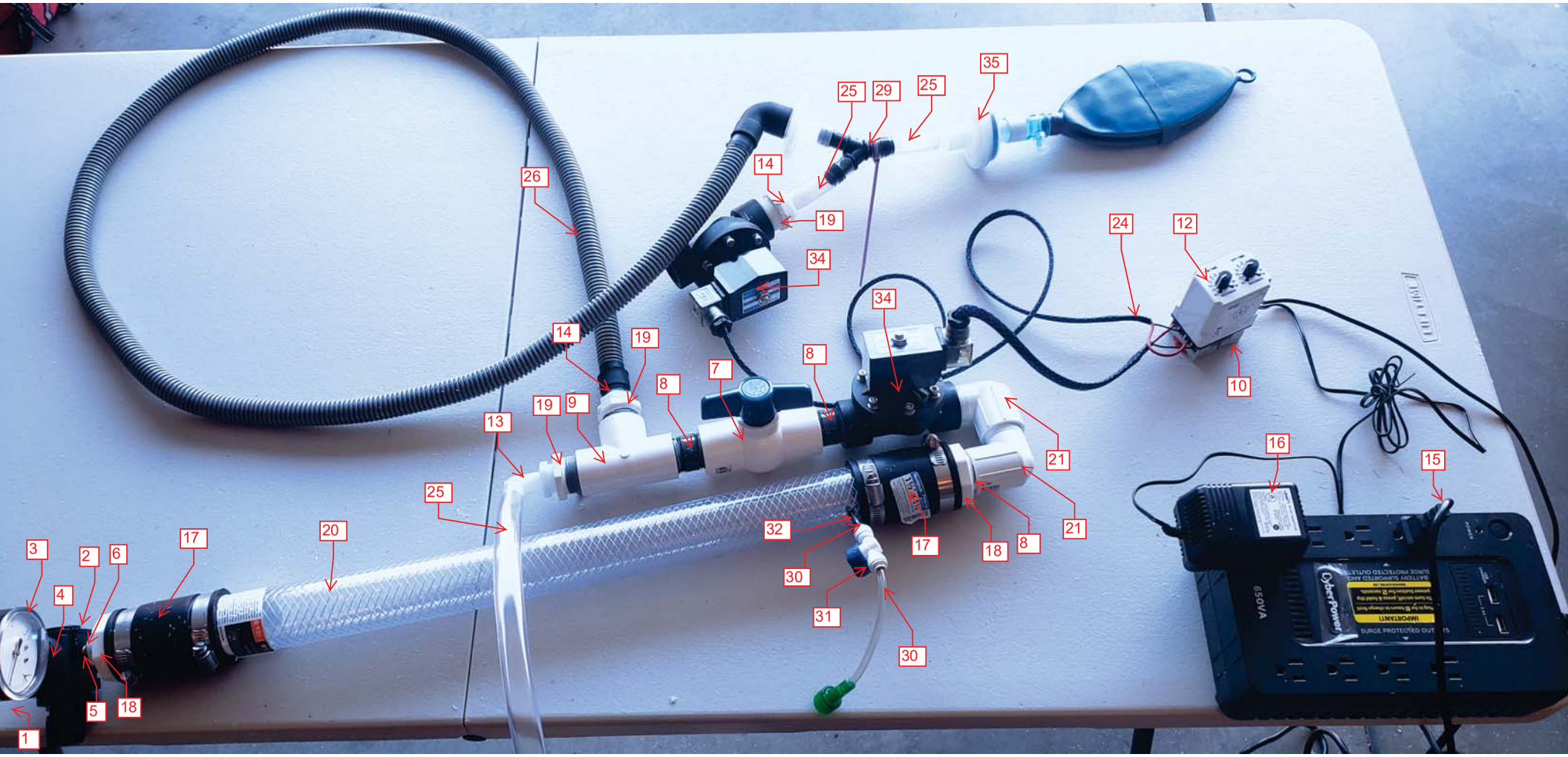
NOTES:

Items may be found for less cost, "Equal" sized/function parts should also be considered to reduce cost

Pricing does not include shipping or your local Sales Tax

Pricing assumes utilization of as many "off-the-shelf" components as possible. Mail-ordered timers and CPAP hoses/filters recommended to reduce risk and cost.

Tools needed for assembly - Screwdriver, demel or drill, scissors/knife, pliers, wrench, wire cutters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