Open Source DIY Ventilator Experiment

NotHari Seldon

Contents

Simple Open Ventilator: Overview

Updates:

4/3/2020: **Tidal volumes look good around 650mL per breath** * TODO: PEEP * TODO: Vary Tidal Volume * TODO: Capture Tidal Volume, Mass, Speed variation in a chart * TODO: Write up Test procedures

Introduction:

Team Seldon is producing plans and prototypes of a ventilator that can be built by tradespeople across the planet from locally obtainable materials. The design is OPEN SOURCE, OPEN DESIGN, and OPEN HARDWARE. You can find all of our progress here. If you want to help please contact - seldonenterprises@protonmail.com. Full details of the build out are here

Starting with the Block Diagram:

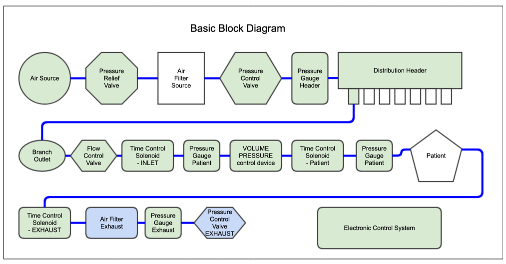


Figure 1: System Block Diagram

The most recent video of progress to date. youtube link .MOV link

We have a paper we are trying to keep up, but it is a few steps behind the github site - Description Document

We also have a lessons learned page

Figure 2: Picture Under Test

Design Requests and Requirements

Several groups have come out with design guidelines and requests. We have captured a few of them here. #OSventilator will have more info

- Vulcan Rapid Vent Requirements
- UK Rapid Vent link
- Canada

Progress to date:

Version 0.89 Complete – Documentation and Testing underway, PEEP still to be implemented. Exhaust side leaking too much.

We are 90% of our goal of being able to create this from all Home Improvement Parts. The controller circuit uses an Arduino and relays we had laying around. Code is posted, circuit is coming.

Technical Constraints

We have limits on the total volume, Respiration rate, and max pressure that can be applied to the balloon. The medical industry uses terms of art we need to convert to more traditional engineering terms.

Tidal Volume – Volume of air that needs to be pushed and pulled out of the balloon: 400-700mL. This is a reasonable amount. We can figure this out.

Pressure mmHg – Standard pressure measurement, but we like to work in PSI. 40mmHg == 0.77PSI. This is too small for our normal measuring tools. We need a way to work with this. Mercury is hard to get and poisonous, we will use water. 1mmHg = 0.535776 inH2O, or about 1.3cmH2O very doable and easy.

Respiration Rate – Fill, wait, exhaust cycles. We call this hysteresis. Simple control problems. 5-30 breaths per minute.

Tunable values

- Tidal Volume 400mL to 600mL
- Respiration Rates 5-30 cycles/min
- Pressure 40mmHg to 60mmHg (21.4 inH2O –> 32 inH2O = Delta 10.6 inches)

Construction Constraints / Mission

We know we can spend money and time to make very nice ventilators. What can we do when we need many more than can be manufactured in a hurry? Can we leverage local tradesman talent and supplies? If we assume our normal scientific supply chain is broken or too slow we have to move to distributed manufacturing with what is in stock. Our group is taking the Apollo 13 approach. What is available in the local stores, and what can local craftsmen construct? Can this be completed with all in stock parts from a local hardware store?

Original Tasks:

- **Create a system absolutely as simple as possible**
- **Create a constant low pressure high volume air supply**
- **Create Safety system to reduce injuries**
- **Create measurement system**
- **Develop and Test Prototype System**
- **Document prototype system**

Donations

If you want to donate to the project you may donate to a developer directly for parts etc:

`BTC: 12VbmzcMsj5VtiCuqSdMPihkLPt9UEqHfd`

Or you can done to a 501(c)3 **The Asymmetrical Biodiversity Studies and Observation Group** (ABSOG) They are working on a direct donation page on GoFundMe

Why are we doing this?

COVID-19 has exposed a critical shortage in our medical care capabilities, and supply chain. (REF Italy doc report). Throwing money at the vendors to produce more and faster is unlikely to work in serious world-wide pandemic where supply-chains are shut down, the need for ventilators vastly outstrips the manufacturing capability, or quarantine simply shuts down transportation.

The total number of ventilators available is around 600-800k(1). Of the total ventilators 80% are currently in use for car accidents, surgery recovery, etc. Even if we had 1M and 20% avail that only leave 200k avail. The CDC is predicting over 1M dead in one model. These people might live if ventilators were available. We think we can help, and it is our duty to help. We don't want doctors and nurses having to choose who lives and who dies in the emergency room based on the number of ventilators available.

(1) Based on off the record conversations with USG officials.

Mission Statement

Henry Watt from Britain during WW2 said –

"'Watt: The system was deliberately developed using existing commercially available technology to speed introduction.[60] The development team could not afford the time to develop and debug new technology. Watt, a pragmatic engineer, believed "third-best" would do if "second-best" would not be available in time and "best" never available at all. – quote from wikipedia"'

What we have volunteering part time

- Doc reviewing our effort
- Senior Hydraulic Engineer
- Master Fabricator
- Senior Electrical Engineer

What we need

- Documentation help
- Fabrication duplication
- Imagineers / Fabricators
- Nurses / PA's
- Makers to help
- Funding for parts & help

Disclaimer Section

Lawyers: This project is to demonstrate the possibility Due to liability issues **No warranty of usefulness at all** * The material on this site is provided with no warranties explicit or implied. * No material on this site is intended to provide medical advice. All designs are intended for investigational use only. * The Department of Health and Human Services (DHHS) has declared liability immunity for medical countermeasures against COVID-19. * This site does not represent any official policies or procedures of anybody. * ref 1 * ref 2 * ref 3 * ref 4 * Federal Register

License

Until we get further guidance the project is licensed as such: * CERN Open Hardware Licence Version 2 - Permissive license

Simple Open Ventilator: System

Updates:

4/3/2020: **Tidal volumes look good around 650mL per breath** * TODO: PEEP * TODO: Vary Tidal Volume * TODO: Capture Tidal Volume, Mass, Speed variation in a chart * TODO: Write up Test procedures

Introduction: Team Seldon is producing plans and prototypes of a ventilator that can be built by tradespeople across the planet from locally obtainable materials.

Progress:

The block diagram shows our progress to date. Green Blocks are designed built and under test

Overall System Design

System Diagram: As currently Implemented

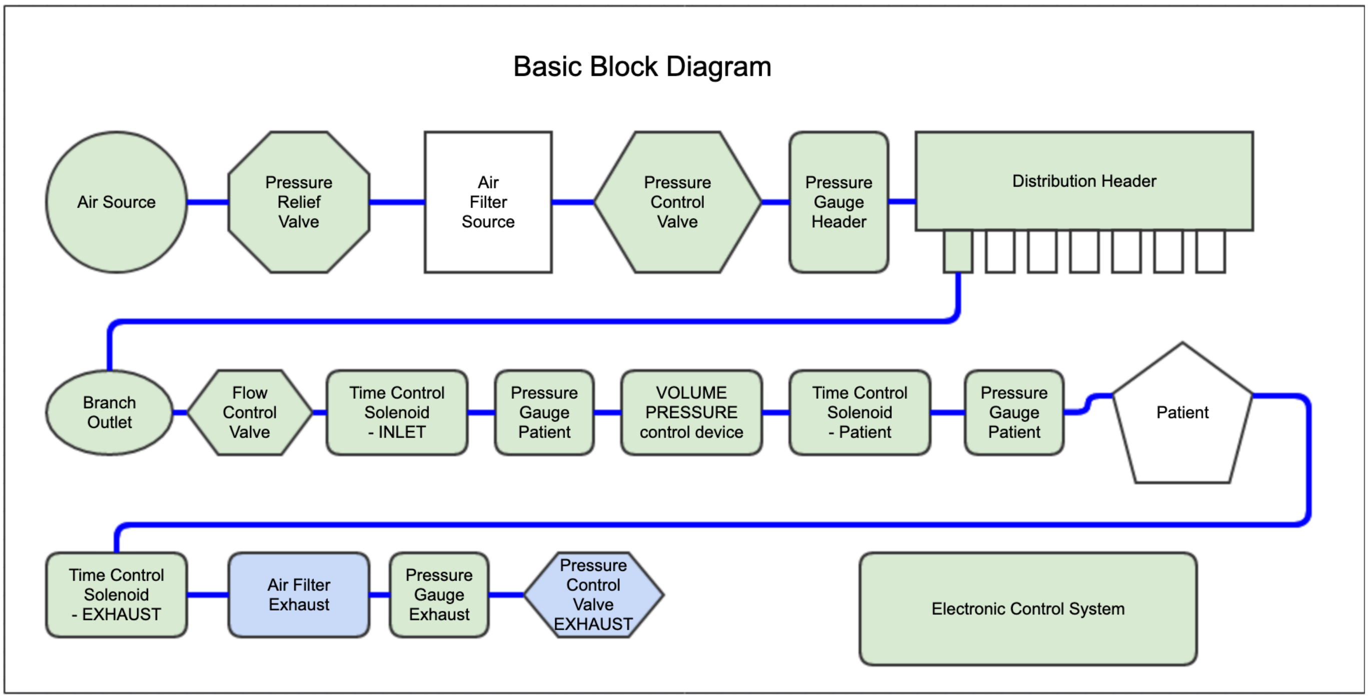


Figure 3: System Block Diagram

More Diagrams under development Document detailing efforts so far.

Major Blocks of the Design

Note: some of these links are not complete yet

- **Air Source**
- **Pressure Relief Valve**

- **Air Filter Source**
- **Pressure Control Valve**
- **Pressure Gauge Header**
- **Distribution Header**
- **Branch Outlet**
- **Flow Control Valve**
- **Time Control Solenoid -INLET**
- **Pressure Gauge - Patient**
- **VOLUME/PRESSURE Control Device**
- **Time Control Solenoid -PATIENT**
- **Pressure Gauge - Patient**
- **Patient – Specifications**
- **Time Control Solenoid -EXHAUST**
- **Air Filter Exhaust**
- **Pressure Control Valve - PEEP**
- **Electronic Control System**
-

  ****Bill Of Materials – Current cost 422.80**

  Ventilator Station – Design Requirements
- - *Tidal Air Measurement and Delivery* - 400mL to 600ML
- - *Respiration Rate* 5-30 Cycles / min
- - *Pressure* 40mmHg - 60mmHg . . . 21.4 inH2O - 32 inH2o
- - *Tidal Air Removal PEEP* 5-24 inH2O
- - *Tidal Air Filtration*

Test and Measurement

- Tidal Volume
- Pressure

Lessons Learned

- Lessons Learned

DISCLAIMER –

See main Page **Lawyers: This project is to demonstrate the possibility**

Air Distribution

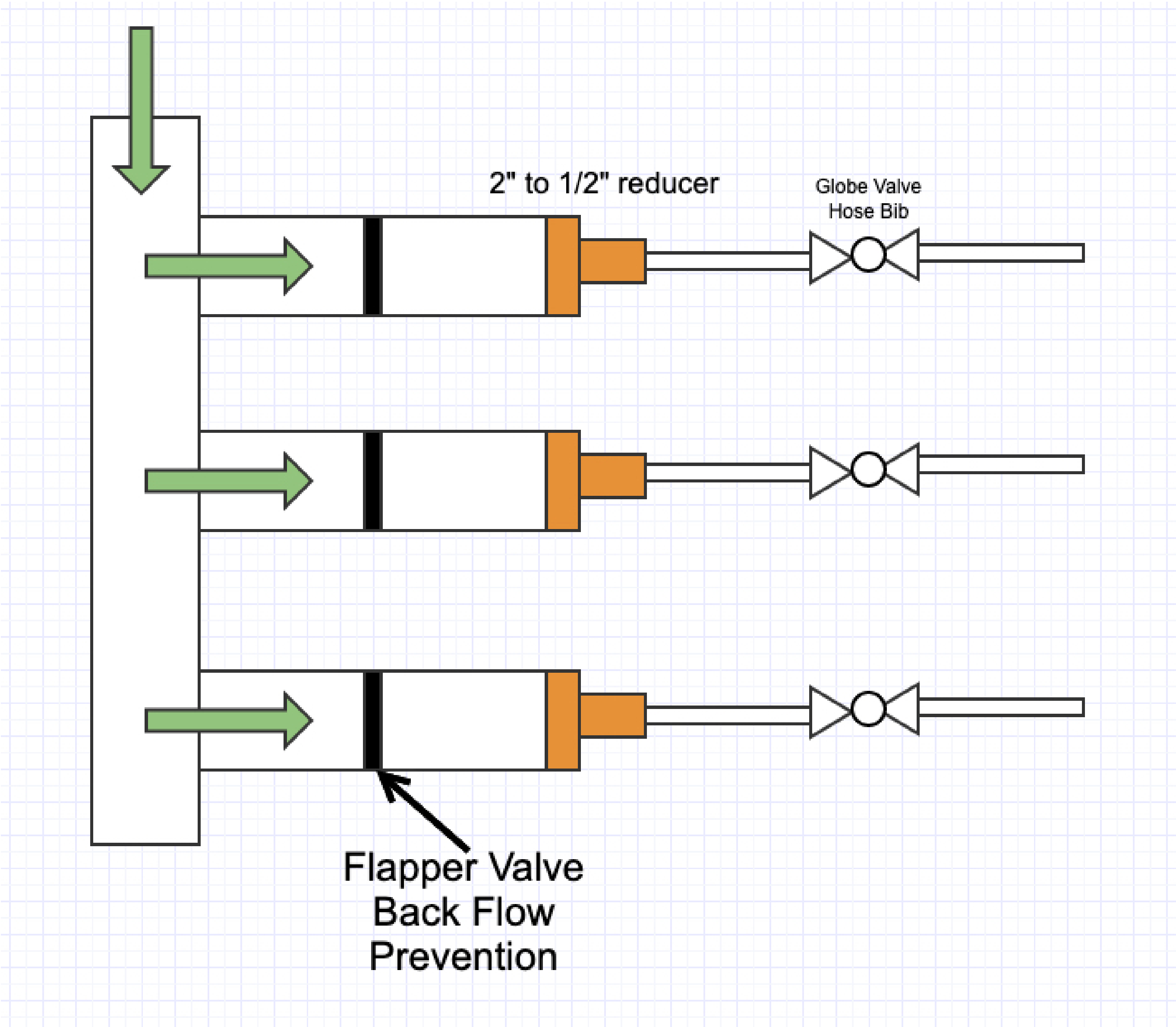
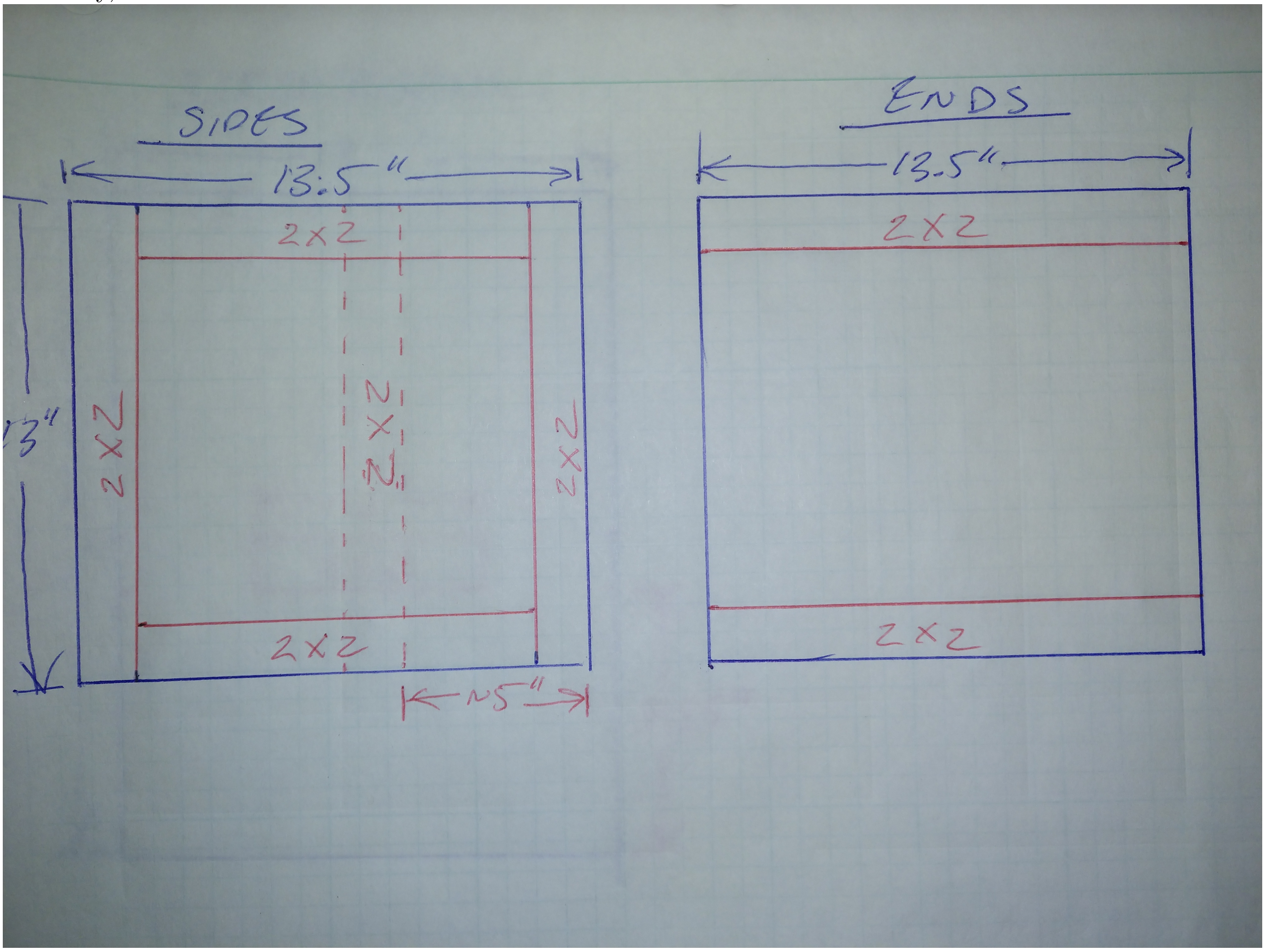


Figure 4: Distribution

TODO: Pictures,Assembly Instructions

Filter v2

Basically, it is crate built with all the cleats on the outside. There are four inside to hold the filter.



The sides should see 500lb total force. Screws have about 100lb pull out so it shouldn't spontaneously dis-assemble.

Here is the filter for it: filter

https://www.blueair.com/us/air-purifier-filters/classic-500-600-series-particle/8.html

Dim: H13" x W9" x L2.8"

Should be able to handle 300CFM with <1in pressure loss.

Air Pressure Delivery

- Simple is best.
- We used a shop vac with a 2" hose and a HEPA filter.

Coupling ShopVac to 2" PVC

Normal Shop vac adapters are for the suction side of the vac. We need the exhaust side to hook into the system. So those wont work, but lucky for us there are ready made parts to hook them up.

You need the following parts: * Shop vac with 2" hose and extensions * 2" Compression fitting Coupler the one that is about 8" long and has screw on caps at both ends and rubber gaskets * a cutting tool

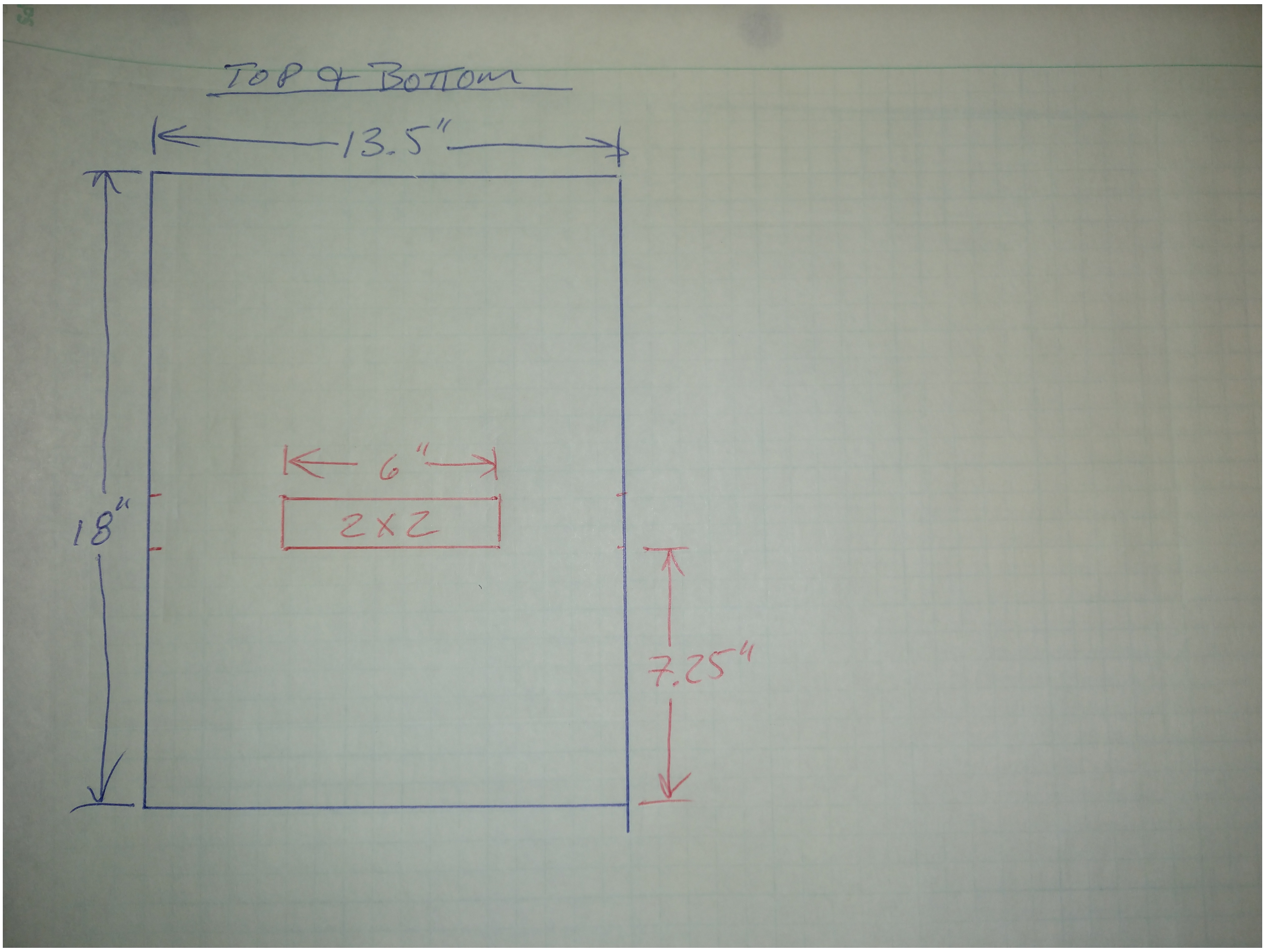


Figure 5: Drawing 2

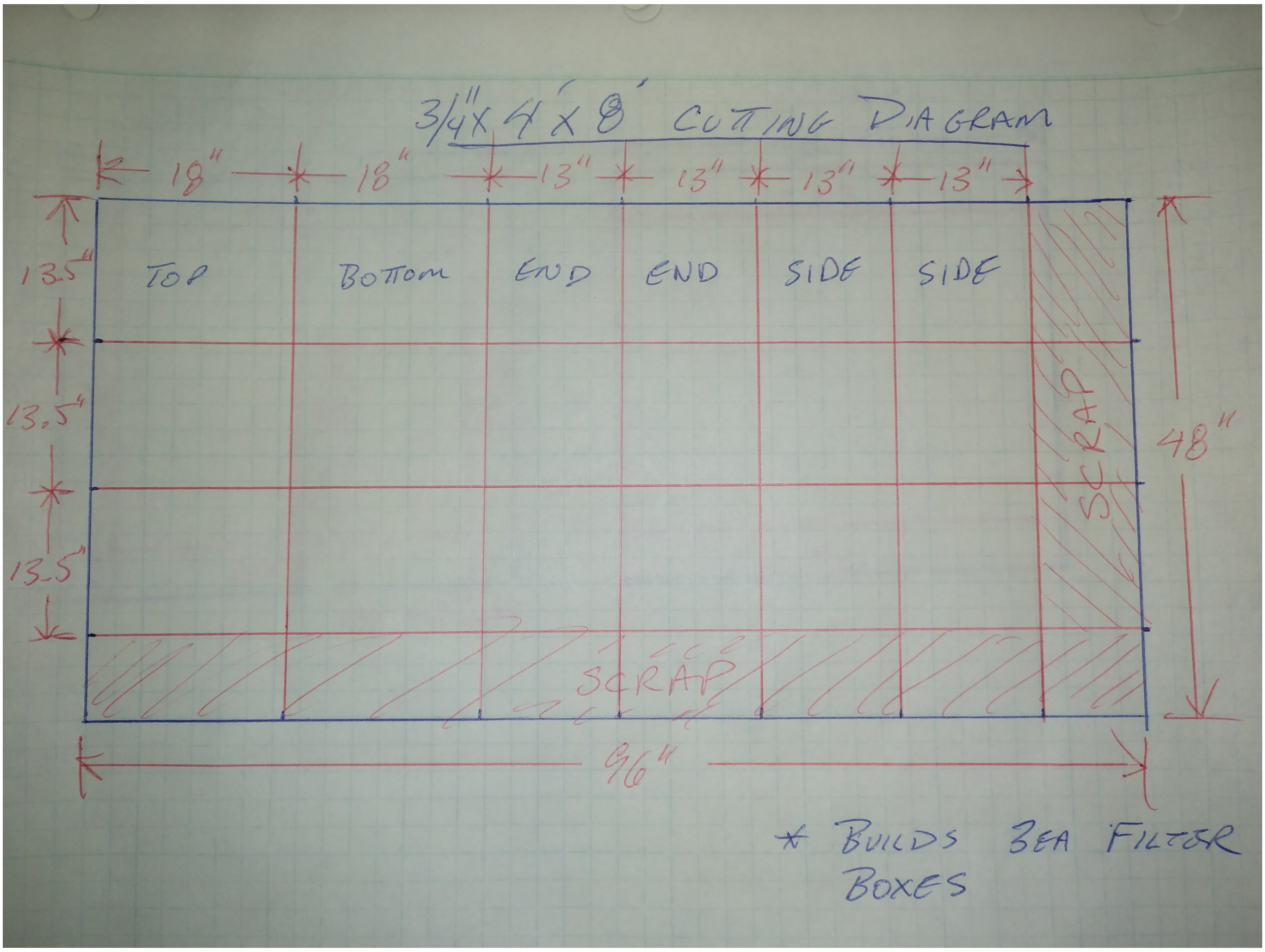


Figure 6: Drawing 3

Assembly

- Hook the hose up to the exhaust.
- Hook one extension to the hose.

- Hook the second extension to the first one.
- Lay the compression down next to the second extension
- Examine the extension and guess where the extension is much smaller than the compression fitting.
- Cut it off there.
- Take the nut and rubber gasket off the compression fitting.
- slide the nut onto the extension
- slide the rubber gasket onto the extension
- try and stuff the rest of the compression fitting on. You may have to trim the vac extension a bit more. If it doesn't go on you have another extension to try.
- Assemble with the hose extension in one side and the 2" PVC on the other side.

You know can blow air into the 2" pipe. This picture just shows the coupler.

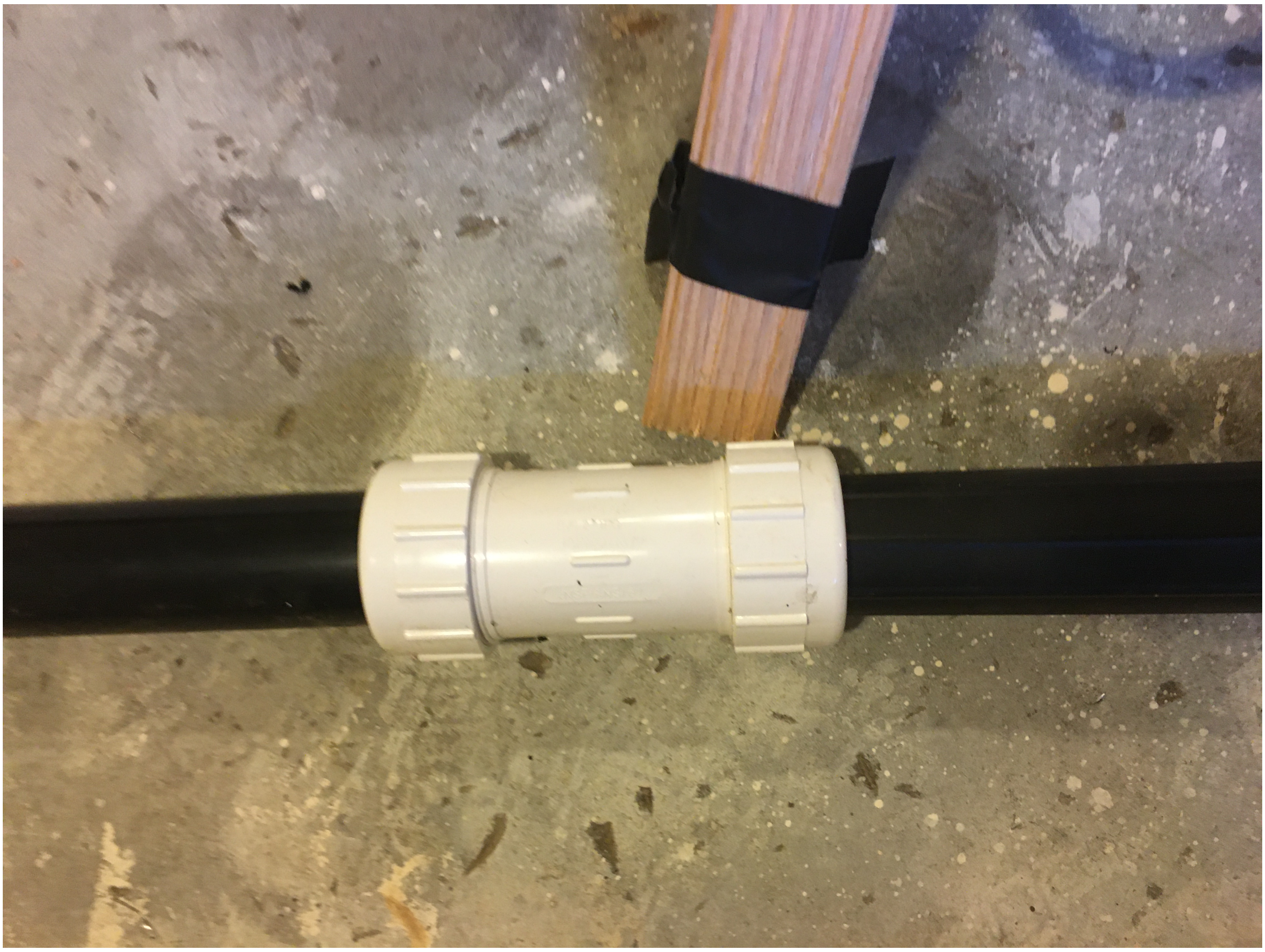


Figure 7: Coupler

We have faith that you can do this one

Air Source

Requirements for the air source is that it delivers sufficient air pressure and volume to drive the system.

Total Tidal Volume Calculations

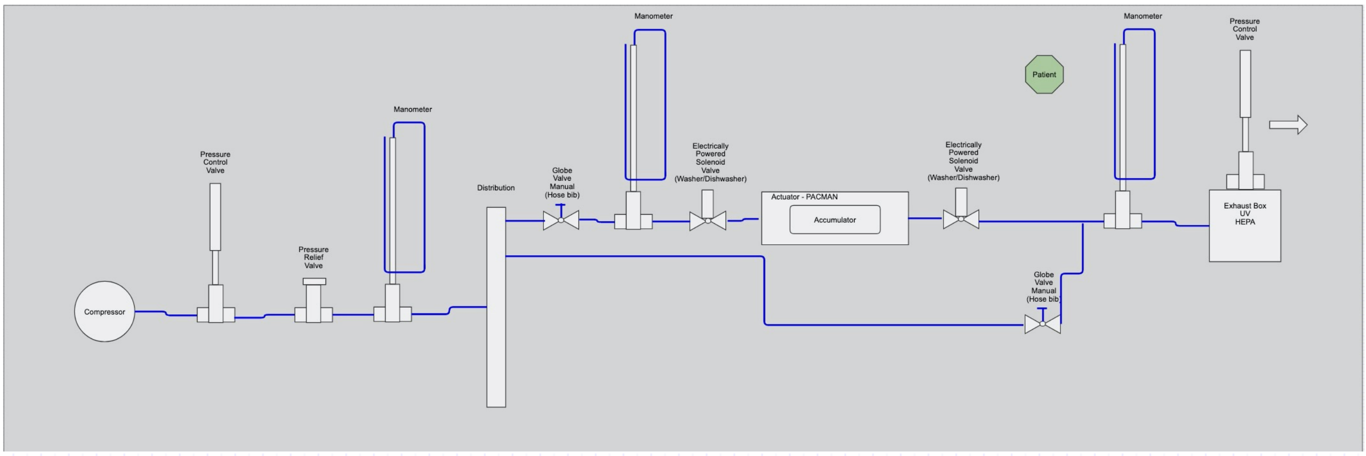
Breaths per minute	Tidal Volume	L / min
5	400mL - 0.4L	2.0L / min
5	700mL - 0.7L	3.5L / min
12	400mL - 0.4L	4.8L / min
12	700mL - 0.7L	8.4L / min
40	400mL - 0.4L	16.0L / min
40	700mL - 0.7L	28.0L / min

The current Air source is a 14 Gal Shop Vac It has plenty of Pressure and Volume

Ambu+ Bag

An Ambu+ bag or equivalent is a human powered ventilator. The device has multiple safety features, valves, volume, and pressure check in it. Below is a drawing of one reverse engineered. This was from the one we had in lab.

Adding and testing clarity of diagrams



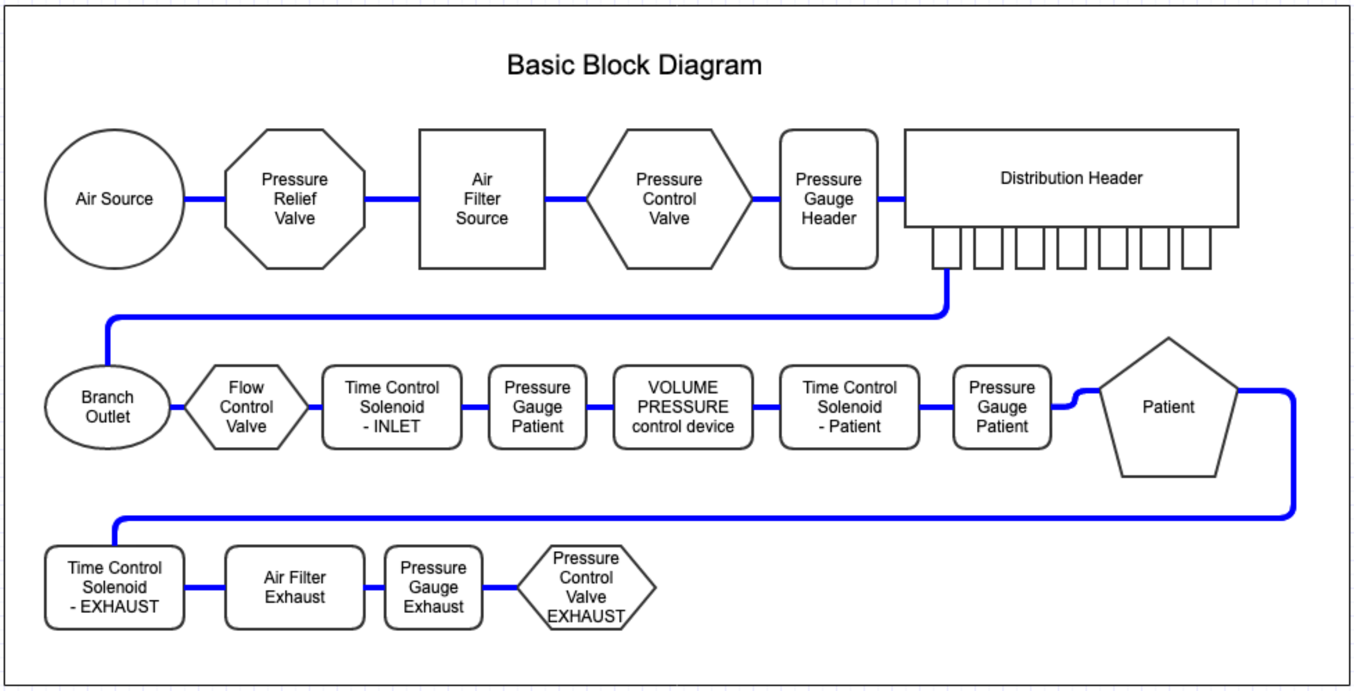


Figure 8: Shop Vac

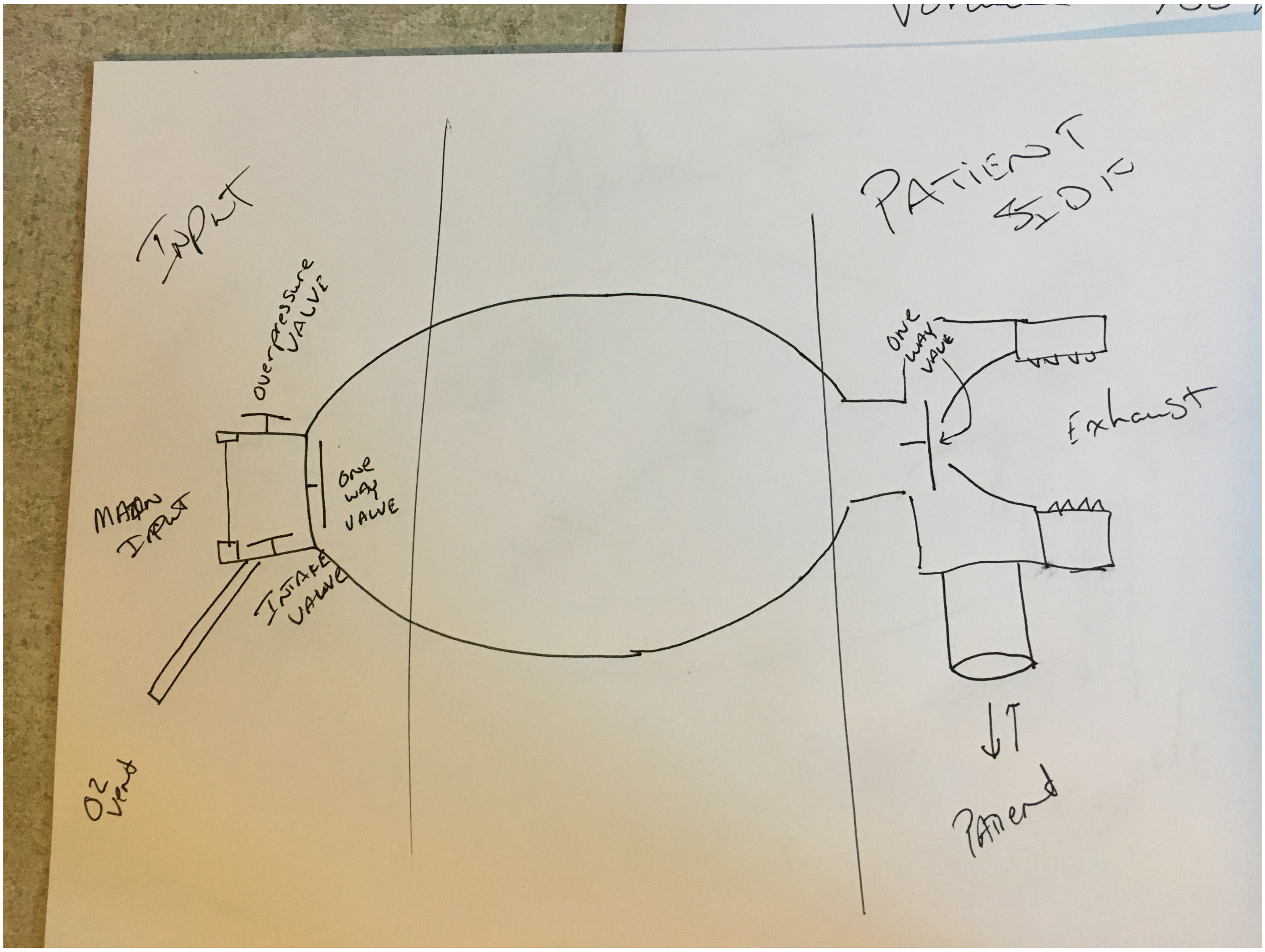
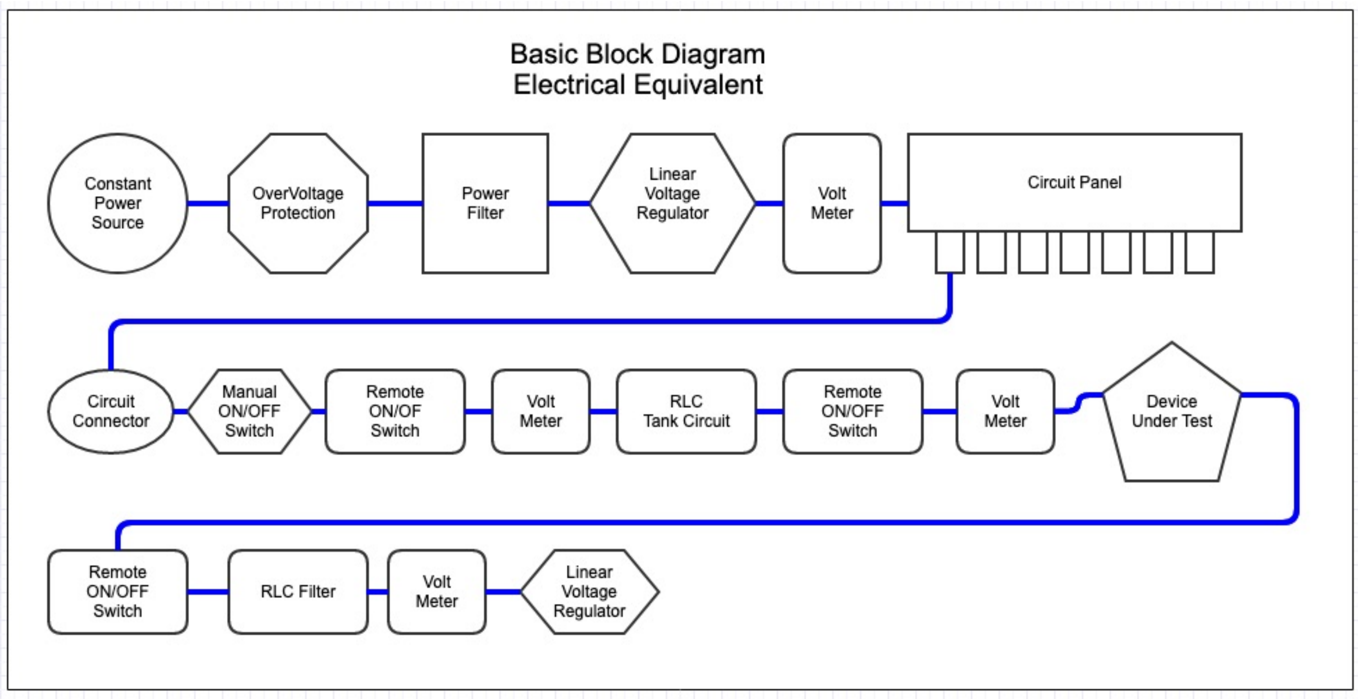


Figure 9: AmbuBag



Electromechanical Control systems

The System is driven by a very simple control system.

Mechanical

3 Valves

Electrical

1 arudino uno 3 relays

Current State:

Control circuit timing is fixed currently. Can be changed by uploading new code with updated constants

TODO:

- Add 2 Potentiometer inputs to vary Pulse width and Period
- Add display showing timing for each
- Add safety stops for out of bounds

TODO: make me

Design Notes & Lessons Learned

During the design, build, iteration, and documentation of this system, we have learned a multitude of lessons. We believe the basic theory, and functionality of the system complete. As with any system there is always room for improvement, but version 1.0 is considered complete. If further funding is provided further testing and refinement for additional field tailoring would be explored

If version 2.0 is commissioned. We believe creating a industrial WOG valve system would be significantly more robust, and easy to produce. As this is a safety of life system the control system would remain simple

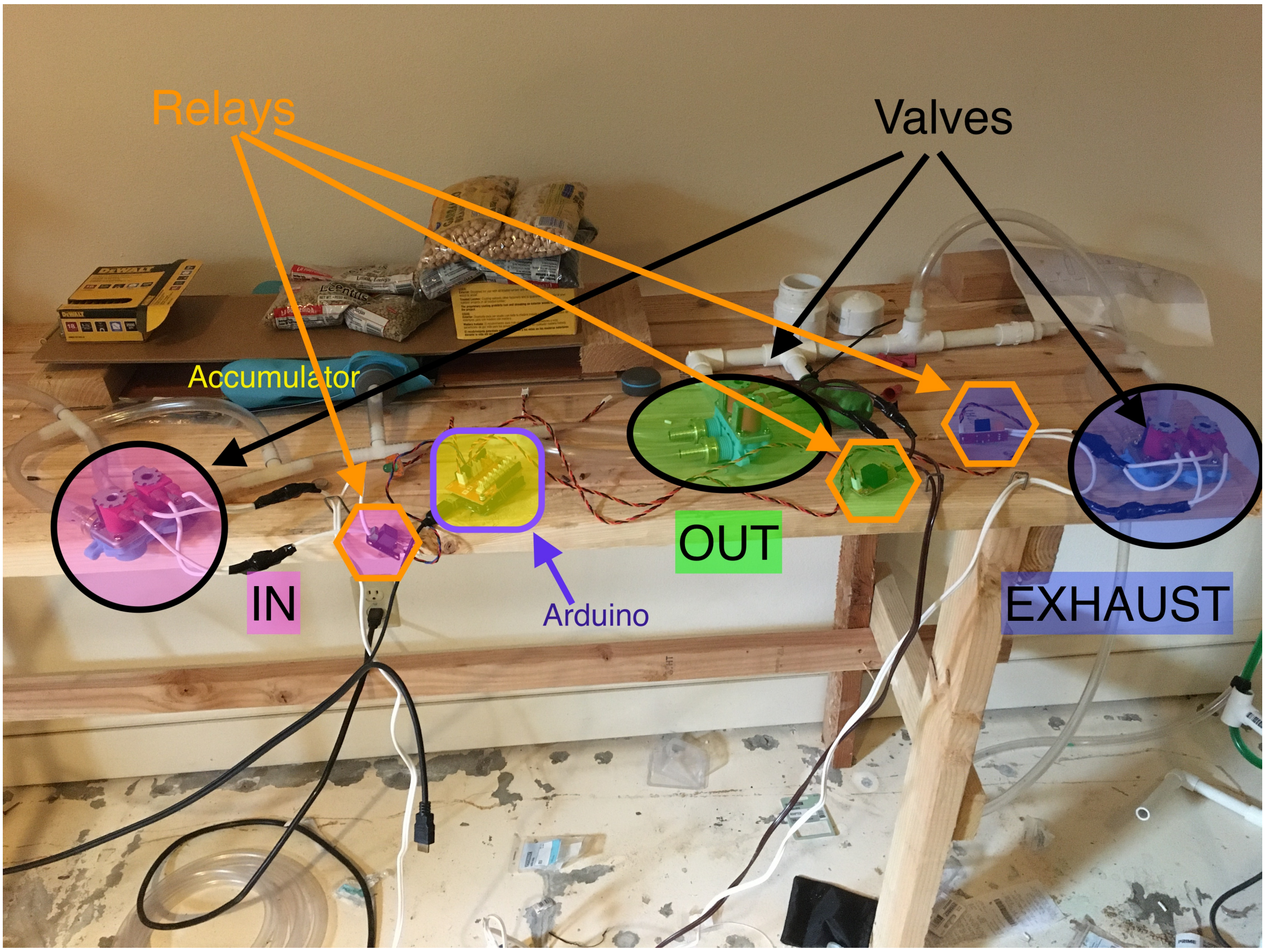


Figure 10: As Built

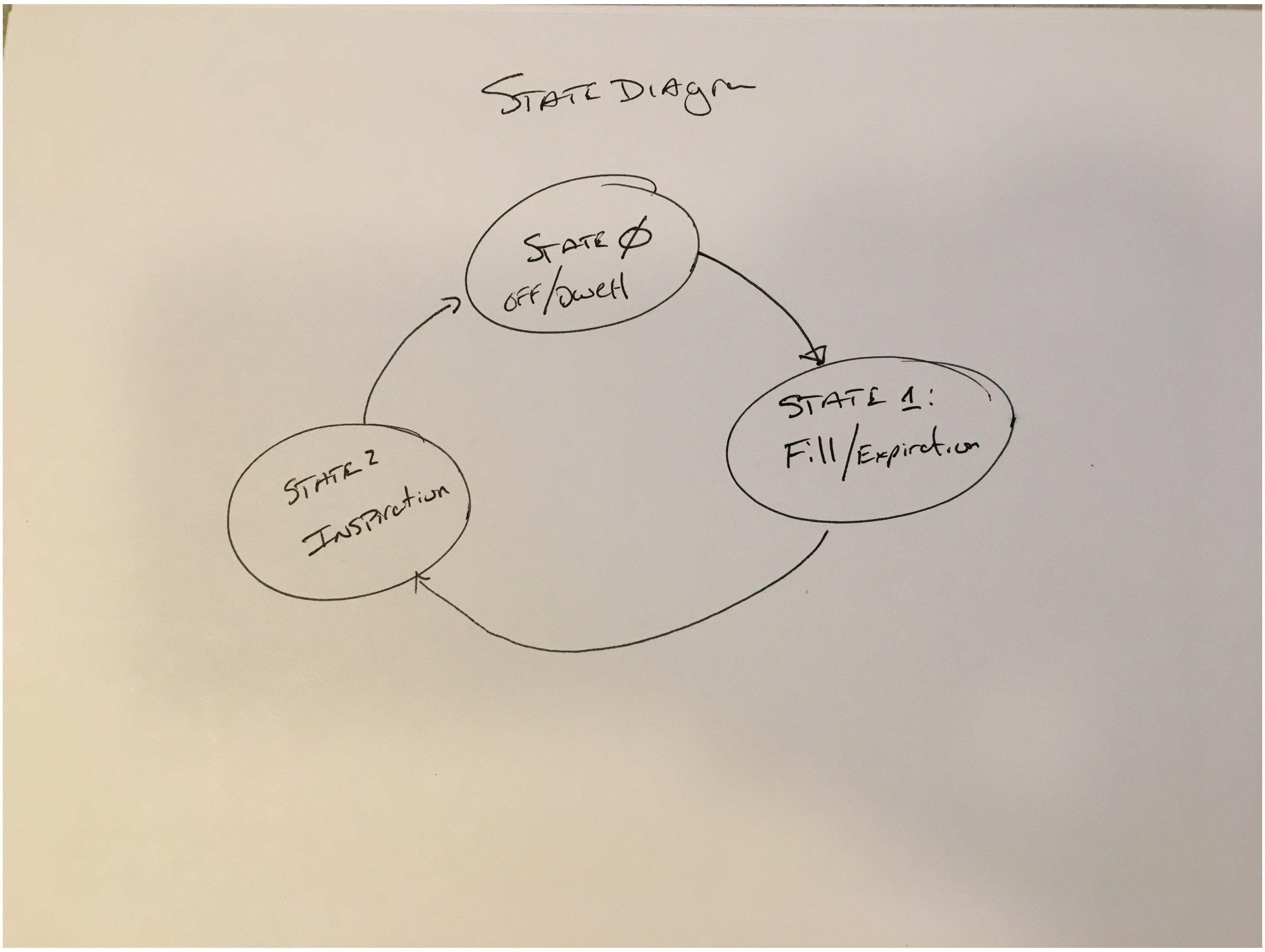


Figure 11: State Diagram

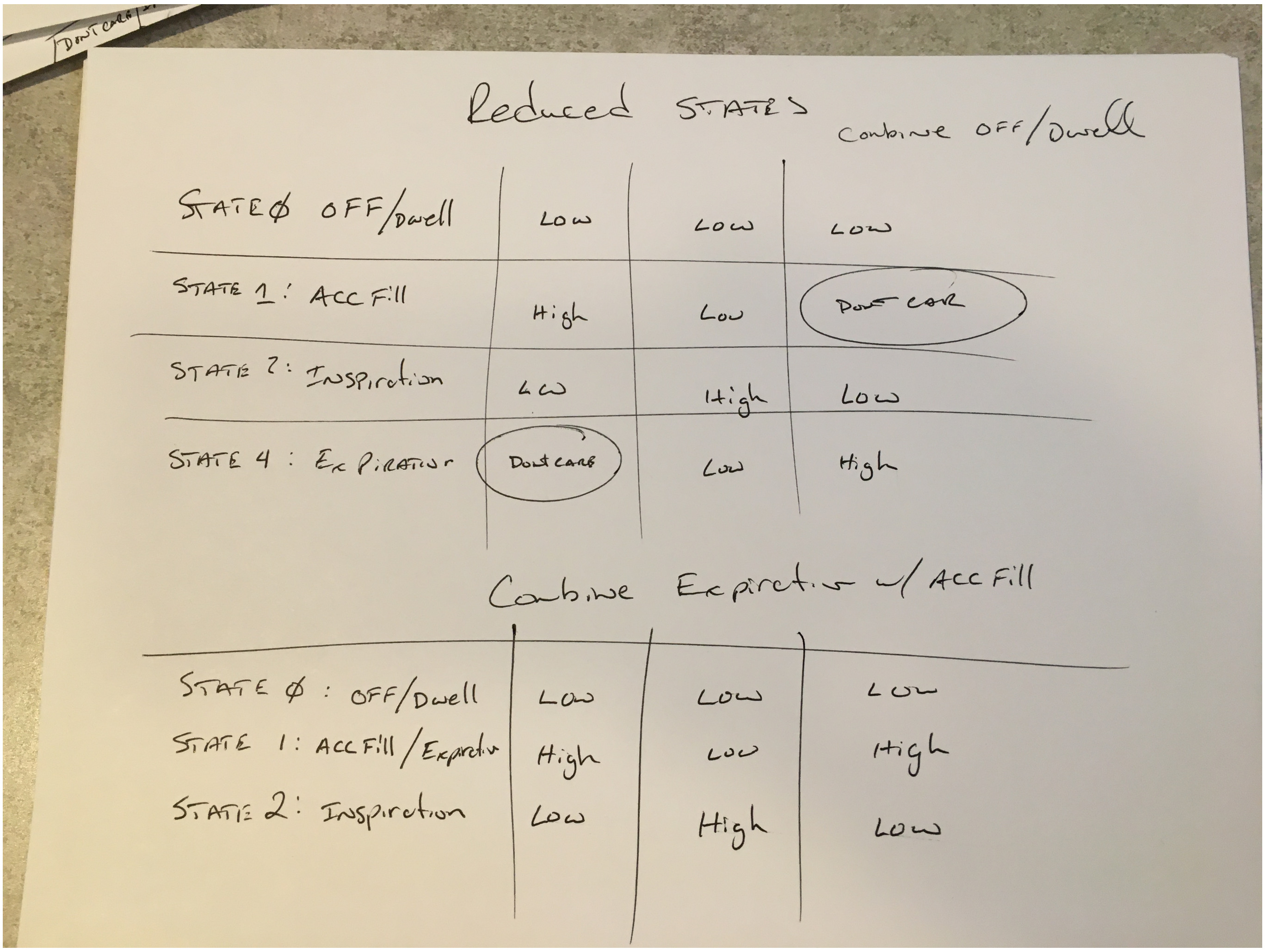


Figure 12: State Variable Chart

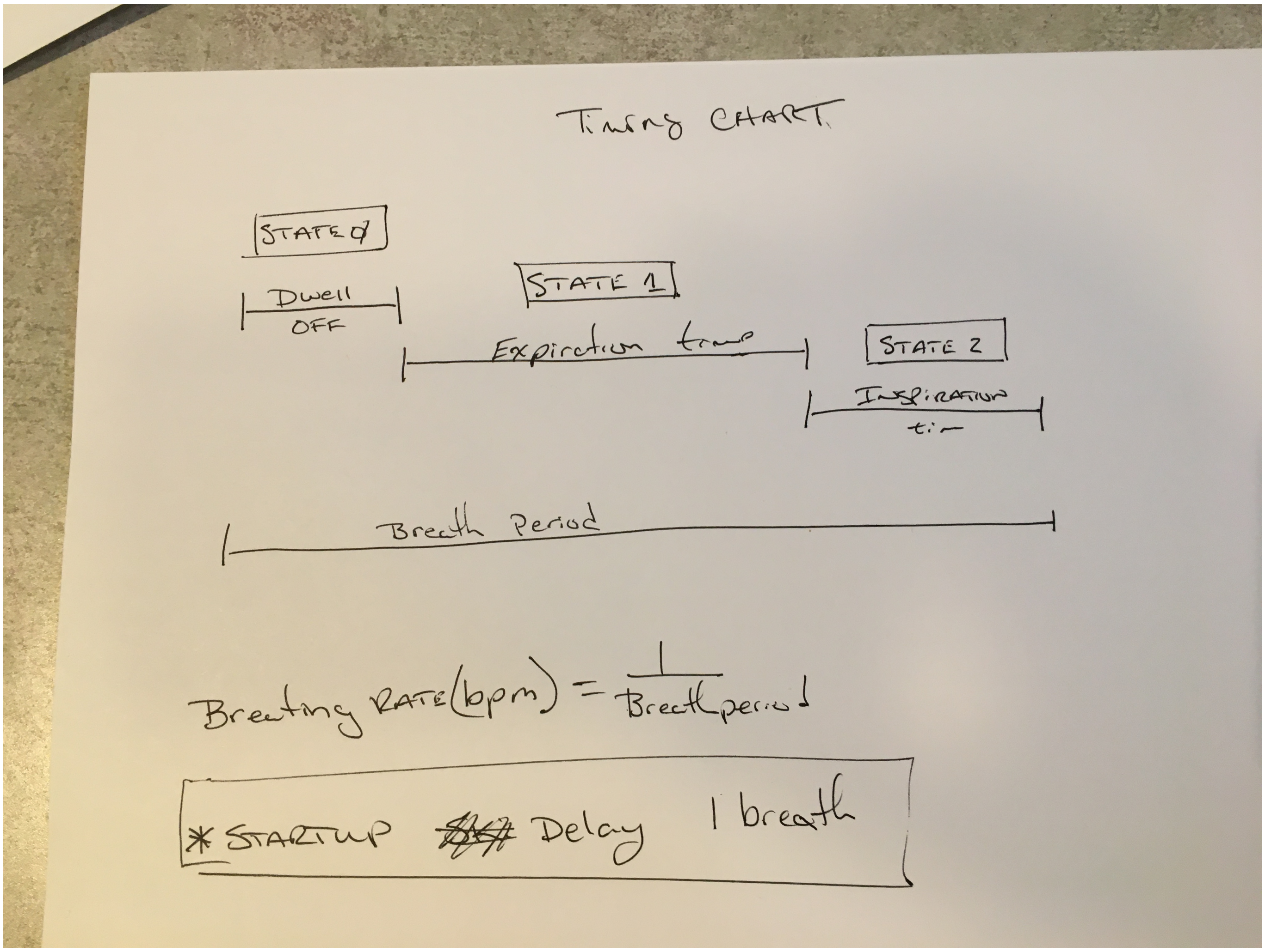


Figure 13: Timing Chart

and robust. Reducing the size to something portable could be accomplished in 30-45 days. Two paths would be appropriate with 2 design teams. * Continue down the field expedient path trading off robustness for capability * Design the system more robustly while exploring parts in the supply chain.

The first option would still enable tradespeople to fabricate the systems. The second option may require some manufacturing fabrication techniques and specialty parts.

Lessons Learned

Gravity: Our Friend –

In designing the system we understood that each of the trades groups would be on their own building these systems. There would be no one to provide oversight and calibrations. We had to keep the designs as simple as possible, and as accurate as possible. We chose gravity, mass, and air pressure as the main methods of controls for the systems. Below is a summation of our impressions:

Basic system concepts

- Only readily available and substitutable parts
- Gravity – pretty constant +/- small error across the planet
- Mass – based on gravity
- Water – readily available
- Air pressure – most trades people need this anyway
- Self measurement and calibration techniques
- – Long Time differences
- – Large Volume changes

Calibration labs use gravity based instrumentation

Concept 1:

The initial concept was to build a pneumatic system that would inflate a manual assist medical ventilation bag automatically. We joined the #OSventilator movement and saw that was already being taken care of with multiple different efforts. We moved on to assist those who will have no access to medical devices.

The best mechanical squasher we have seen is the Virgin Space (Branson) rotational electric motor driven version. It is super simple to control and fabricate. It replaces the human with a very nice robust mechanical squasher that can deliver repeated precise performance. The squasher should outlast the bag easily. Fabrication should easily be in the 1000's per week depending on bag and motor availability.

Developing and testing the highest risk items: (PCV & Measurement)

The hypothesis that we could use a shop vac (blower side) to power the system had to be developed first. A shop vac is a constant power device. Meaning if the input or output becomes partially blocked the pressure increases and the flow decreases. We needed a constant pressure system. To accomplish this we needed a way to measure the pressure to even start.

Manometer development

The medical folks we talked with before the Vulcan Challenge came out told us that we needed to maintain between 40-60mmHg. Mercury is a bit challenging and difficult to obtain and use safely. Luckily for us 1mmHg is just over 1/2" H2O. 60mmHg is 32.15".

A manometer is just a U shaped tube filled with a fluid. In our case it was water. 18" on both sides gives us a possible 36" of height measurement. We started with less and sent water squirting across the lab it really needs to be 24" tall to get good differential measurements. We added food coloring to make the measurements that much easier. We went through several designs, before landing on the final one that is super simple, low cost ($35 for 3) and highly accurate.

Manometer is necessary, otherwise we are just guessing, and likely to injure someone

Pressure Control Valve

We went through multiple iterations. We knew what we needed to build. A weight floating above a pipe that leaked air perpendicular to the force. The weight was not going to magically be stable, so we needed a robust method that would guild the weight as it moved up and down. The area needed to be large enough to lift a significant weight. By using a largish weight and force area, we could account for large power swings, and the sensitivity of the system to exact weights was decreased. Our initial thoughts were around coinage. Coinage mass is highly regulated and accurate. The pressure could easily be adjusted with pocket change.

But making a method to keep the coinage still was challenge. We eventually settled on a steel pipe inside a standpipe with a cap that went overlapped the standpipe.

Our first build sent the lid into the ceiling of the lab. *After COVID crisis is over, we will be launching all sorts of things with this system.* Version 1 of our manometer also sprayed water at the same time. We added some air drain holes to the overlapping cap, and it began to behave well.

Version 1 of the PCV and manometer were too complicated, we then did several iterations on these two items to reach near our final design.

Input filter testing

The main critical parts of the system now functional. We moved on to testing Input air filtering.

Our First experimental concept was to use a shop vac as an air source, and filter the output. The hypothesis was to push air into a large box with 1-3 HEPA filters and UV lighting. The Large box should provide nice low speed laminar flow through the filters providing for heavier particle to sink to the floor of the filter box. The low speed laminar flow greatly aids that. The HEPA filters provide the additional filtering, and the UV lighting in the box kills significant living bacteria, virii, and other living things in the suspended air. The box was constructed using cardboard, tape, shower drain fittings, and a HEPA filter.

We placed a manometer on the input and output of the cardboard filter box. It was basically a super lossy filter. Input pressure was a nice 30 inH2O, output pressure was around 4 inH2O. This was a failed experiment

Output:

- Shower Drain assemblies make good I/O ports as they are 2"
- Our manometers work nicely
- Filters need to be assembled like crates with the structure on the outside.

Filters have been put on hold, as it is a construction exercise

Emergency Pressure Relief Valve: – SAFETY

We understand that we are new to this world, but in the sub-sea engineering field safety is always a concern. We added a Pressure Relief Valve to the design. This makes the system inherently safe to the patient as the supply pressure cannot exceed a maximum set value. We know this will work, but we are unclear if we need it yet. Build is complete, but testing is delayed.

Accumulator

Next is how to get that constant pressure to cycle to ON/OFF. We began to think of this as an automated bellows. The Ambu+ bag is designed to work just that way. We examined the build of the bag and noticed the complex network of mechanical valves that make the bag work, and keep the patient safe.

Experiment 1:

We were going to use the Ambu+ bag as the accumulator. We tried it by stuffing the 1/2" pipe in the input side and blew air constantly, pumping the bag up nicely. We needed something that would squash the bag reliably. The bag is shaped like a football and must be held for operation. We decided a PACMAN or board on a hinge was the easiest method to fabricate.

After Version 1 of PACMAN was complete, We attempted to use the Ambu+ bag, but could not get it to reliably fill as the input side of the bag had too many relief valves. And we couldn't get a good enough seal to lift the weight.

Experiment 2:

Replacement of Ambu+ bag with Turkey Roasting bag. We fabricated a seal with two PVC plumbing parts, a 2" coupler and a 2" to 3/4 Reducer. This worked remarkably well.

Experiment 3:

Replacement of turkey bag with water bag. This gave us a more robust bag and a bit more control. This what is currently being used.

PACMAN

Version 1: 1 4' piece of leftover laminate flooring and a piano hinge

This went poorly, the piano hinge was wrong for 2 reasons. We needed it to fully close, but the hinge is optimized for fully opening. And it does not cut very well.

Version 2: left over door hinge and laminate flooring

This also went poorly as the carriage bolts, we had available prevented the closing of the hinge

Verison 3: Hinge mounted to 2x4 block

This version works pretty well.

Version 3a: 2x4 screwed to deck

During testing it bounced too much

Version 3b: 1x8 replaced top board

Weight required for squashing and thin laminate flexed and bounced too much.

Valving

Now that we had pressure control, measurement capability, and an accumulator. It was time to move to controlling the accumulator. We initially checked basic functionality with manual valves. Turning them one at a time to see results. We had positive outcome. It was time for electrically controlled valves.

We examined a multitude of possibilities.

- Our goto was Grainger for industrial WOG (Water, Oil, Gas) valves, but with a cost over $100 each that was going to bust the budget.
- Irrigation valves were a possibility, but they are gear driven ball valves. They are not potable water safe, and they are too slow.
- New touch valves for kitchen sinks, but the cost was prohibitive again.

One of our engineers was driving when the spotted an appliance repair shop. The shop had a generic Hot/Cold water valve for a dishwasher. We bought a couple of used ones and a new one for experimentation. The valves have a garden hose fittings on the input side and a clamp bib on the output.

We installed one and checked basic flow. It worked. Later we would find out that some valves have check valves that that have to be drilled out. But more importantly the valve are directional. Input must come in garden side and out crimp side.

We also found later that we needed both Hot and Cold to get enough flow to operate the system. Basic functionality was checked by manually plugging and unplugging the power to each valve. We quickly moved to electrical control.

Electrical Control system

The valves that were selected are 120V solenoid driven valves. When voltage is applied the valve opens, otherwise they are normally closed to prevent water flow. A more traditional WOG poppet valve would be better, but those are not available at local hardware stores or readily scavenged. We are using a microcontroller in place of analog mono-stable multivibrator (PWM circuit) that could be built from several dimmer knobs, caps, power supply and 2 relays. We will detail that in the future.

As this is a system that needs to be highly reliable, we selected one of the simplest microcontrollers that is readily available, the lowly Arduino. The valves only need to be opened and closed for specific time periods. Details are here. This portion went really well as expected with a bunch of EE's and ET's on the job. Simple is BEST!

Next on the agenda is adding variability

- Period - **Breaths per minute**
- Pulse Width - **Inspiration time**
- Dwell time - **Breath Hold**

using simple potentiometers and 7 segment displays. Keeping it very simple.

Test and Measurement:

Accurate field testing needs to be completed to calibrate these systems built in the field.

- **Pressure Testing** – Manometers are very simple for pressure checks. Measurement with yardsticks or meter sticks are sufficient. We can put a yardstick in it and record the video to check max pressure and plot pressure profile
- **Volumetric testing** – Attempting to measure individual tidal values is a fools errand. The system moves slow enough to test using averaging techniques. For this step we needed another accumulator of known volume. Then we attached it to the patient output of the system. We start with the bag empty, evacuated, and flat. We then turn on the system. After the system is stable 1-5 cycles, we open the temporary valve connecting the patient output to the bag. We then observe the bag and count the number of cycles to fully inflate the bag.

For example we have an 8L bag. It takes 12 cycles to fully inflate the bag. 8L / 12 cycles = (8/12) L/cycle ~ 666mL per cycle with weight (x LBS) Our desired tidal Volume is 400-700mL. We are smack in the middle.

- **Volumetric Error** Assuming that your estimation is either -1 or +1 on the count of fully inflated 8L / 11 cycles = (8/11) 720mL 8.1% error 8L / 12 cycles = (8/12) 666mL 8L / 13 cycles = (8/13) 615mL 7.6% error

To reduce the error using a much larger vessel will reduce the percentage error.

- **Tidal Timing** – We control this at the millisecond level. Verification is performed the same way – count for 1 min and record.
- **PEEP** – Measured with manometer

Low Pressure Manometer

Having a means of reliably measuring pressure is critical to the performance of any ventilator. The readily available pressure gauges are typically designed for tire pressures 15-100psi. We are concerned with slightly negative pressure or slightly positive. The medical field measures in mmHg. We don't have that readily available, but we do have water available.

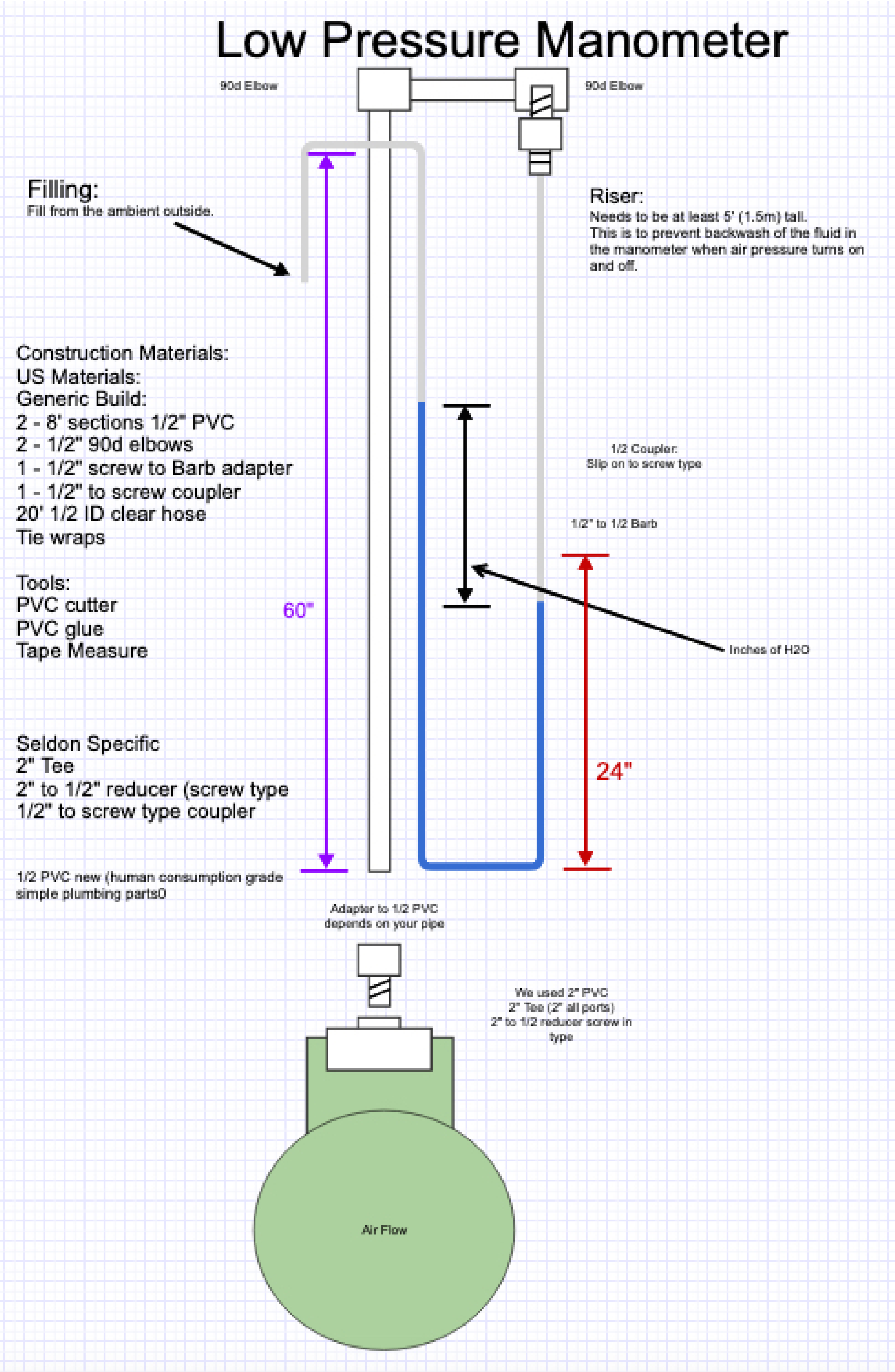
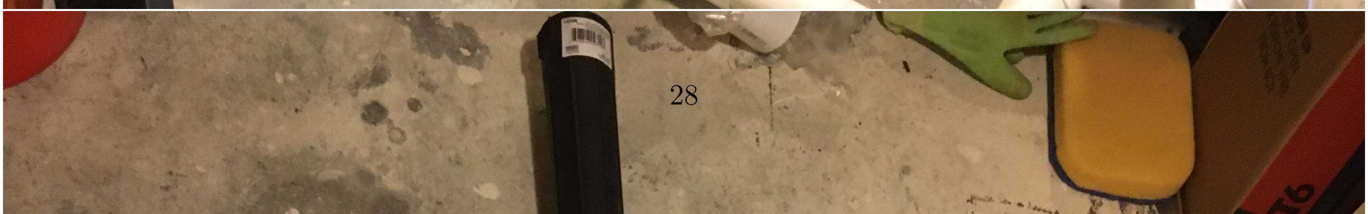


Figure 14: Simplified

Design Drawing

Images



Measured 39" of pressure..

Lessons Learned

It is relatively easy to make a manometer, clear tubing and some water, but as I learned keeping the water out of the flow and in the tube is easy, but takes a bit of ingenuity. Mostly it just takes height.

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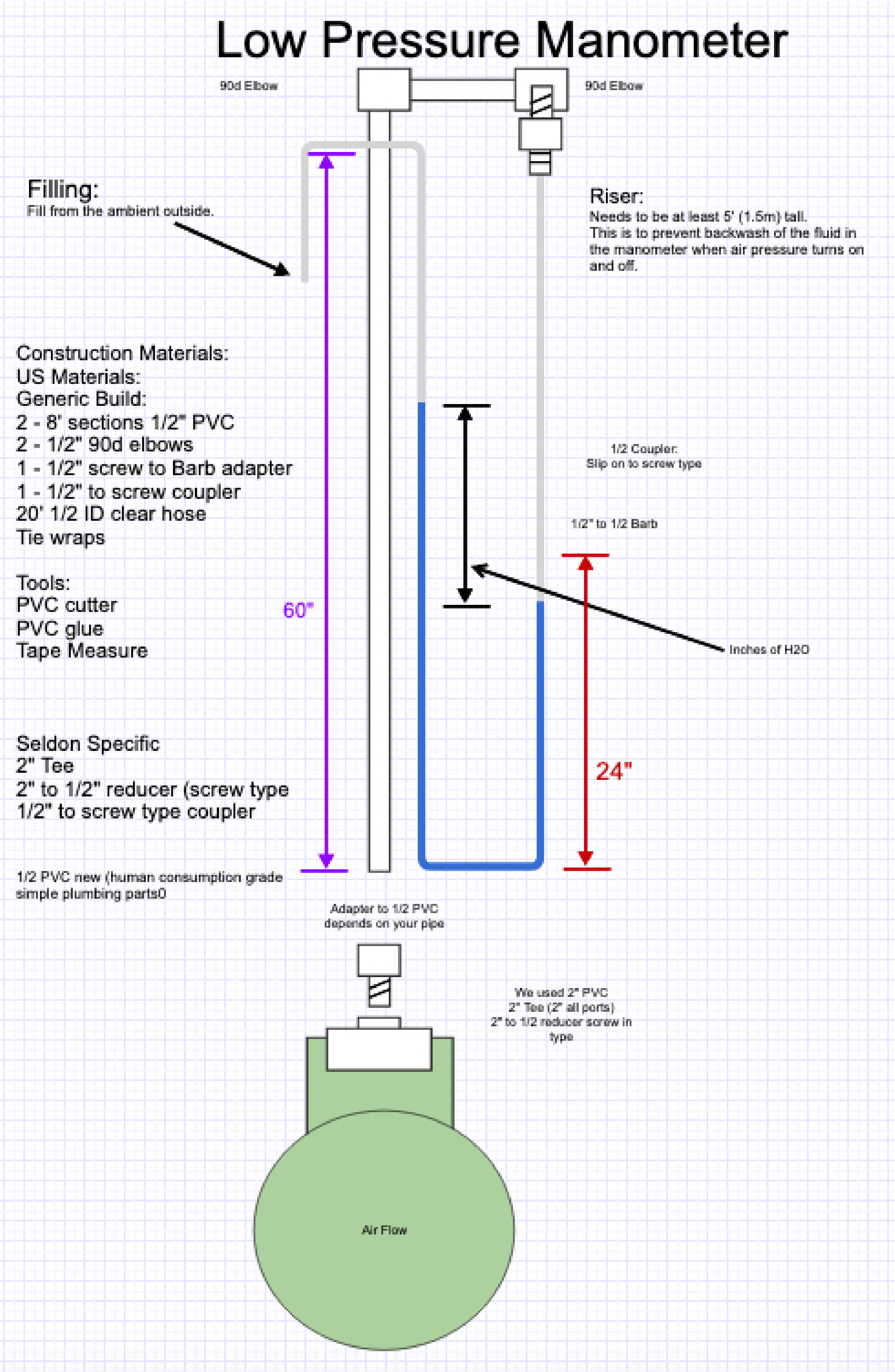
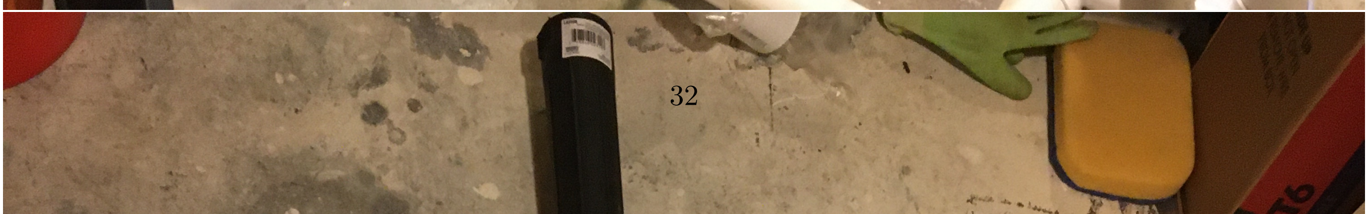


Figure 15: Simplified

Design Drawing

Images



Measured 39" of pressure..

Lessons Learned

It is relatively easy to make a manometer, clear tubing and some water, but as I learned keeping the water out of the flow and in the tube is easy, but takes a bit of ingenuity. Mostly it just takes height.

Pressure Control Valve

Current Version 3.0

Current Design

Concept

Gravity, air pressure can equal out. If the air flow can leak out we can maintain a certain pressure with balance. The air flowing up a standpipe and out the hole has a certain force over a given area. If we place a weight that has a tiny bit less force with gravity as the air has pressure going up, the weight will begin to float. Enabling us to calculate the air pressure.

We are moving from theoretical to practical. We have too many unknowns to fully calculate the absolute correct mass, but we did just build a Low Pressure Manometer. We know from that our approx weight desired for a pressure of 40mmHg is about 2.5lbs. So We are going to build the following.

Then put this on a 4' vertical 1.5" PVC Stand Pipe.

When you turn on the shopvac the first time, expect the weight assembly to go flying. You are going to need to decrease the resistance for the escaping air. Start with drilling 1/4" holes about an inch down from the bottom of the coupler.

This is where we begin difference measurements. You have to have the manometer already built and in place. You are going to adjust the length of the pipe and the holes to get the desired inH2O measurement.

Conversion values

1 inH2O = 1.866463mmHg 1 cmH2O = 0.734824mmHg

Observations

You will notice the Manometer sloshing about depending on the load. Remember 1" is less than 2mmHG. 2" is less than a 10% variation, AND the AMBUBAG is regulating what the patient sees. Fluctuations in the primary system should never be transferred to the patient.

Notes

Update

Pressure control valve success today (16 Mar 20). maintained 24" with a 1/2 hole wide open. Weight based option worked. We had to add orifaces in the side of the cap to reduce the escape air resistance.

Theory:

< insert better explanation >

The pressure control valve and monitoring system is critical to the design operating as intended. The pressure controls the system and fills the accumulator that helps the patient breathe. So over-pressurization is bad but not terrible.

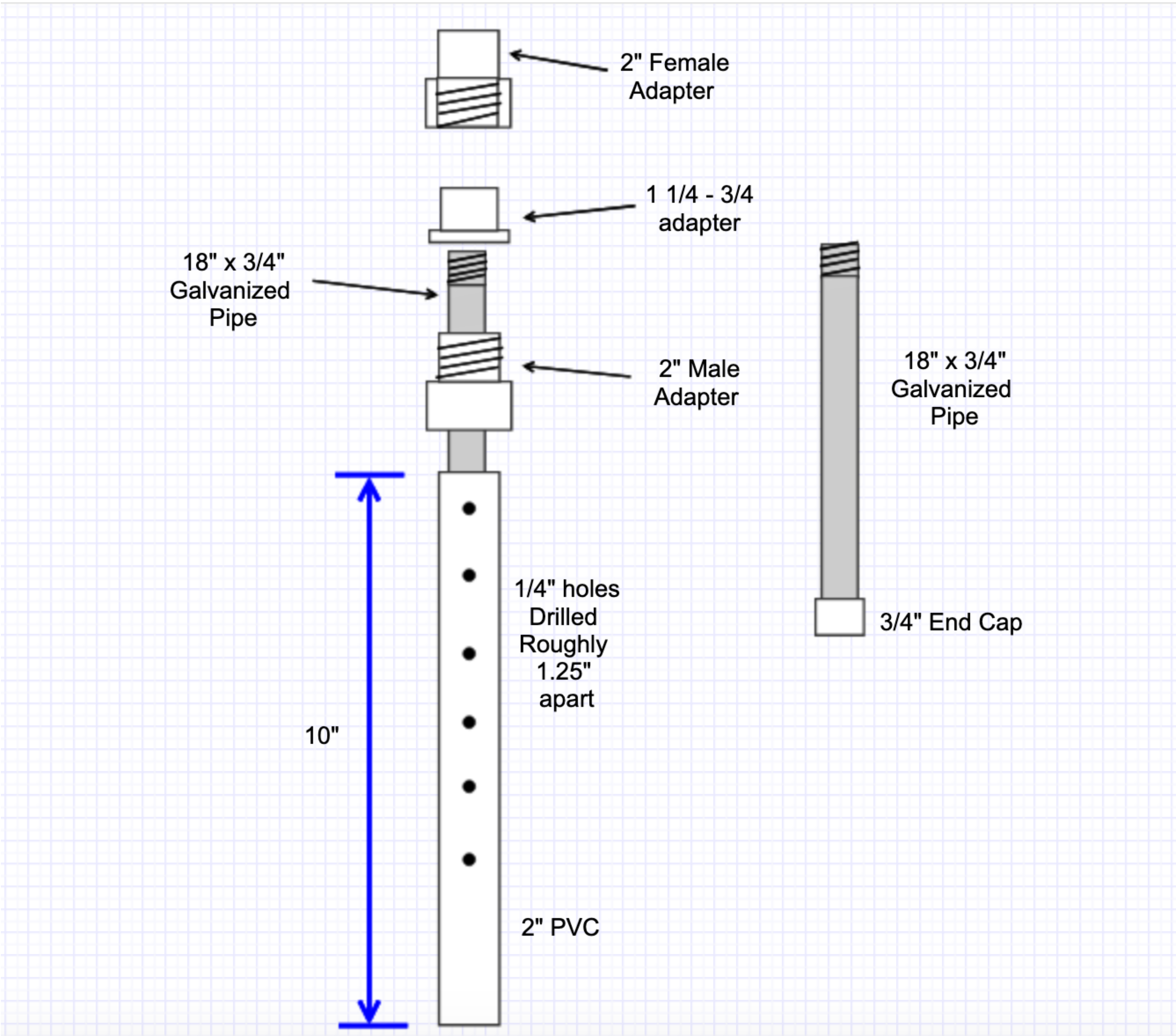


Figure 16: Weight Assembly Drawing

Version 3 / Experiment 3

Slight changes in design to make changing weight easier, and more controlled hole drilling for airflow exit. Confirmed working with globe valve, manometer, and mark 1 eyeball. TODO: Post newest Desigs.

Verison 2 / Experiment 2

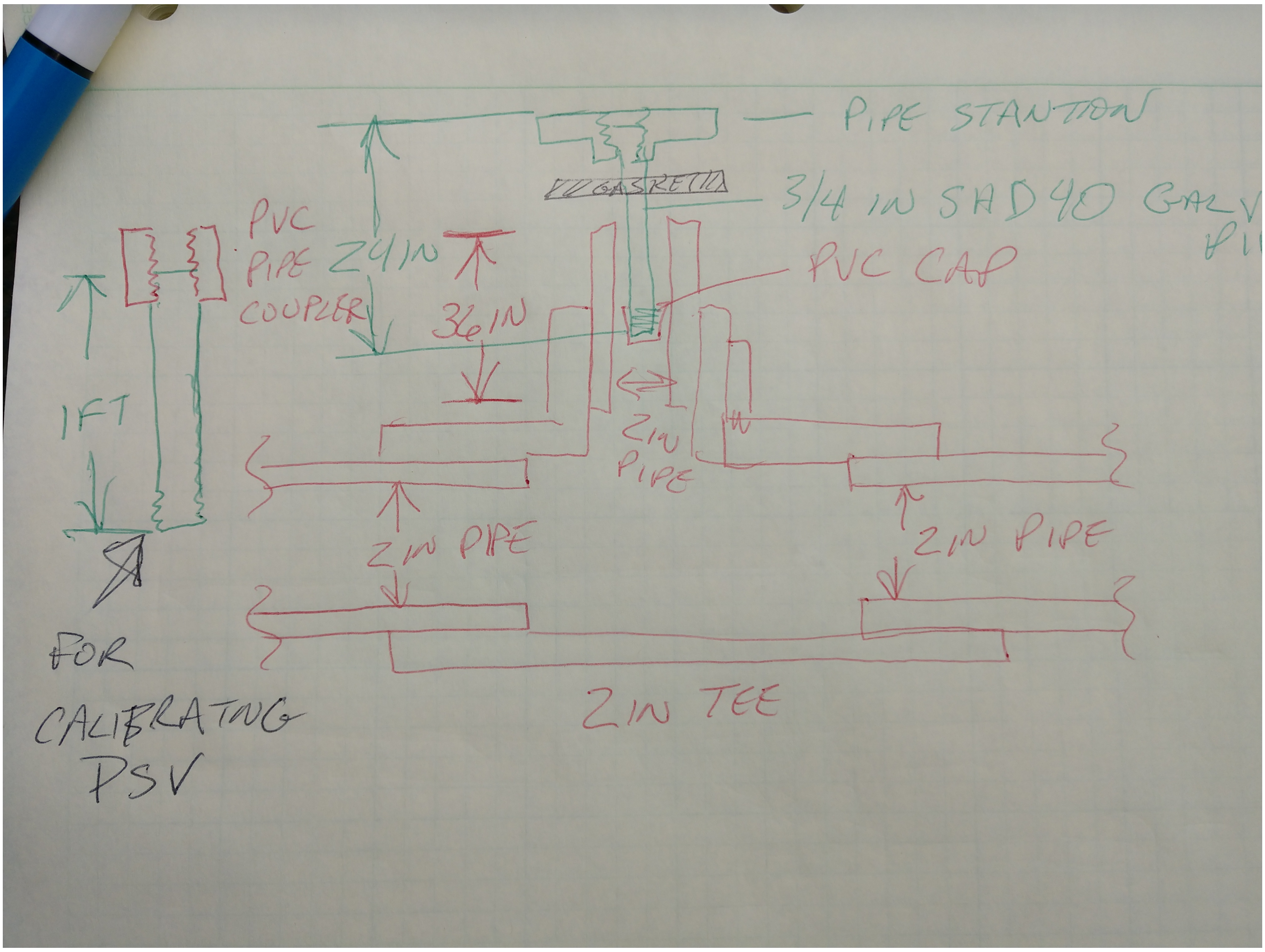


Figure 17: Original Sketch

Version / Experiment 1

The design has undergone the first iteration. The original proposed design Original sketch Drawing The monitoring system As Drawn 2 As Drawn 2

Air Distribution

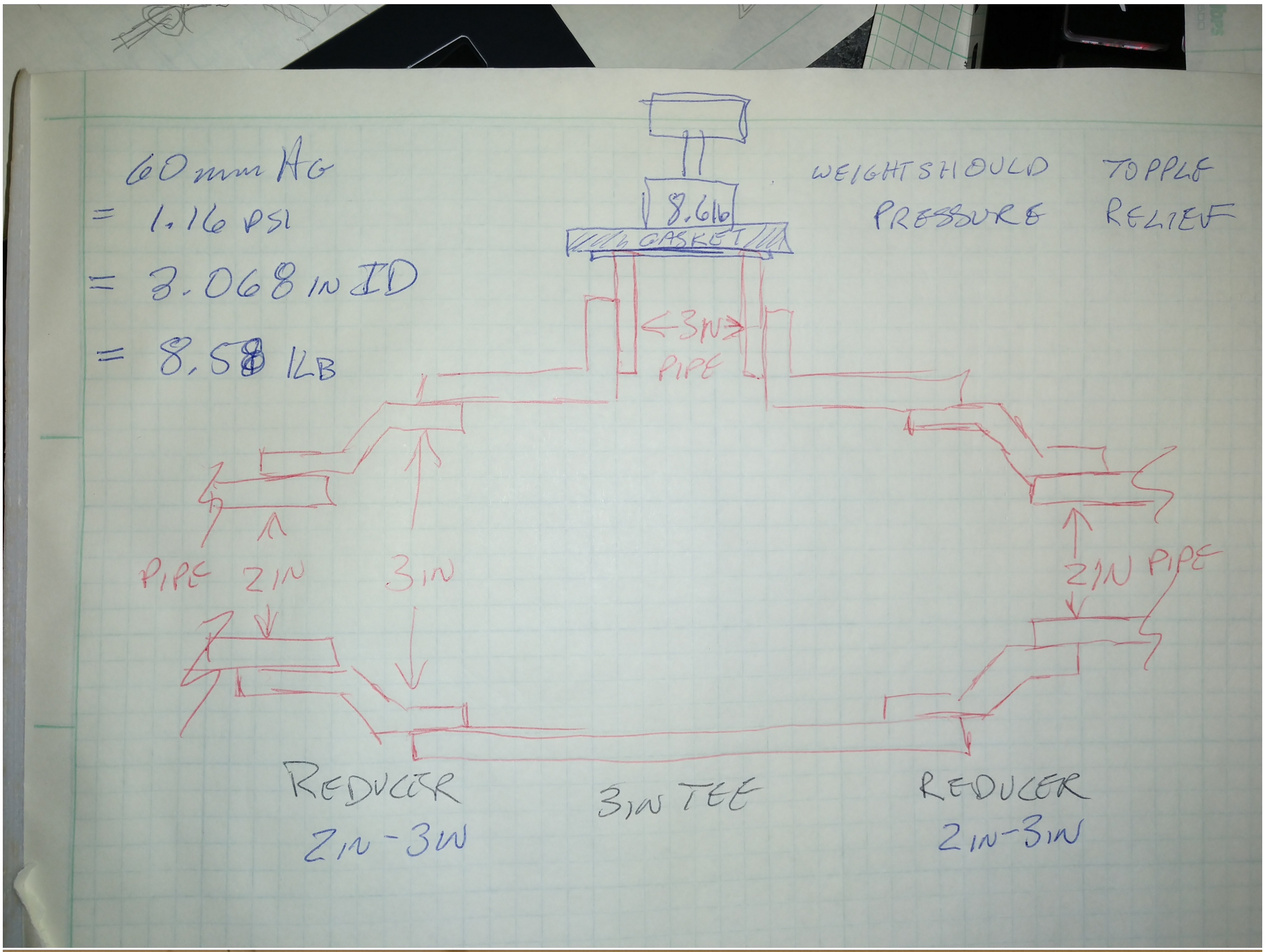
Simply Put 2" PVC to 1/2" PVC with hose bib for individual ports.

Pressure Relief Valve

Basic gravity pressure relief valve. When overpressure occurs, the lid tilts knocking the weight off and opening the line to ambient air. Valve tilted at a 10degree angle to ensure proper operation.

TODO: Document and Test

Version 2


60 mm HG
= 1.16 PSI
= 3.068 IN ID
= 8.58 LB
8.616
GASKET
<-3IN->
PIPE
WEIGHT SHOULD TOPPLE
PRESSURE RELIEF
PIPE 2IN
3IN
2IN PIPE
REDUCER
2IN-3IN
3IN TEE
REDUCER
2IN-3IN

Version 1

OBE

Appendix A: Vulcan-SOF

SOW: Study Ad-Hoc Distributed Manufacturing of un-approved ventilators

Introduction:

COVID-19 has exposed a critical shortage in our medical care capabilities, and supply chain. Throwing money at the vendors to produce more and faster is unlikely to work in serious world-wide pandemic where supply-chains are shut down, the need for ventilators vastly outstrips the manufacturing capability, or quarantine simply shuts down transportation.

Motivation:

The total number of ventilators available is around 600-800k. Of the total ventilators, 80% are currently in use for car accidents, surgery recovery, etc. Even if we had 1M and 20% avail that only leave 200k avail. The CDC is predicting over 1M dead in one model.

Question:

Can a ventilator be produced from locally procured parts by local tradespeople with no skills in the medical industry in an emergency.

Outcome:

Proof of Concept for Quick Reactionary Capability with distributed production for medical or other emergency requirements.

Deliverable:

- Attempt to produce a design spec, instructions, guides, and test procedures enabling local tradespeople to assemble and test the system.
- Test design for reproducibility. Generate after action report.

Expectations:

This is an impossible task.

- Traditional FDA approved ventilators are complex pieces of machinery.
- Innovating a design and a functioning prototype over a 2-week period of time is a near impossible task. It is unlikely that an ideal system can be developed that meets all the desired specifications and requirements.
- However, it IS possible to get close!

Impossible Specifications:

In order of **descending importance**, the ideal desired specifications of a Do-It- Yourself mechanical ventilator are: 1. Total Cost of all parts <$300 2. Able to be assembled and operated by low-skill levels 3. Assembled from readily available, consumer off-the-shelf parts and capabilities (Home 3D printers acceptable) 4. Capable of functioning for at least 48 hours 5. Needs to accommodate a standard 22 mm size hose that is 5 feet long (Hose design not necessary) 6. Have a connection method to allow an adjustable O2 source to be connected 7. Capable of providing a Respiratory Rate of 12-40 breaths per minute 8. Capable of Providing 5-24 cm H20 of PEEP (Positive End Expiratory Pressure) 9. Capable of Delivering Tidal Volumes of at least 500cc (range 160-1500cc) with every breath 10. Capable of limiting the Peak Inspiratory Pressure to 18-40 cm H20 11. Has a method to humidify the air being delivered (in line Passive humidifiers or alternative) 12. Powered using 120V or lower (12 V car battery) 13. Inspiratory Time of 0.4 seconds 14. Gauges or instruments to visualize delivered values and settings

Super Long shots:

A. Provide ability to control Flow during inspiration, but if fixed: able to deliver 60L/min

B. Pressure Support—a breath triggers either a set pressure or volume of air

C. maintains a continuous PEEP (Positive End Expiratory Pressure)

D. Expired air scrubbing–method of absorbing or filtering the expired air

Documentation

Notes regarding Pressure Control

- Pressure Relief – Pops open and stays open
- - Relief size approximately 2x the area of the pipe
- - Example: Using a Tee 1/2 in 1/2 out with a 3/4 T fitting.
- - The T side would be the pressure relief side

Methodology

Our concept is that almost all parts needed for the system can be acquired at your local plumbing and home improvement store. The system is based on pneumatics, not electronics. This makes assembly, modification, and repair possible remotely.

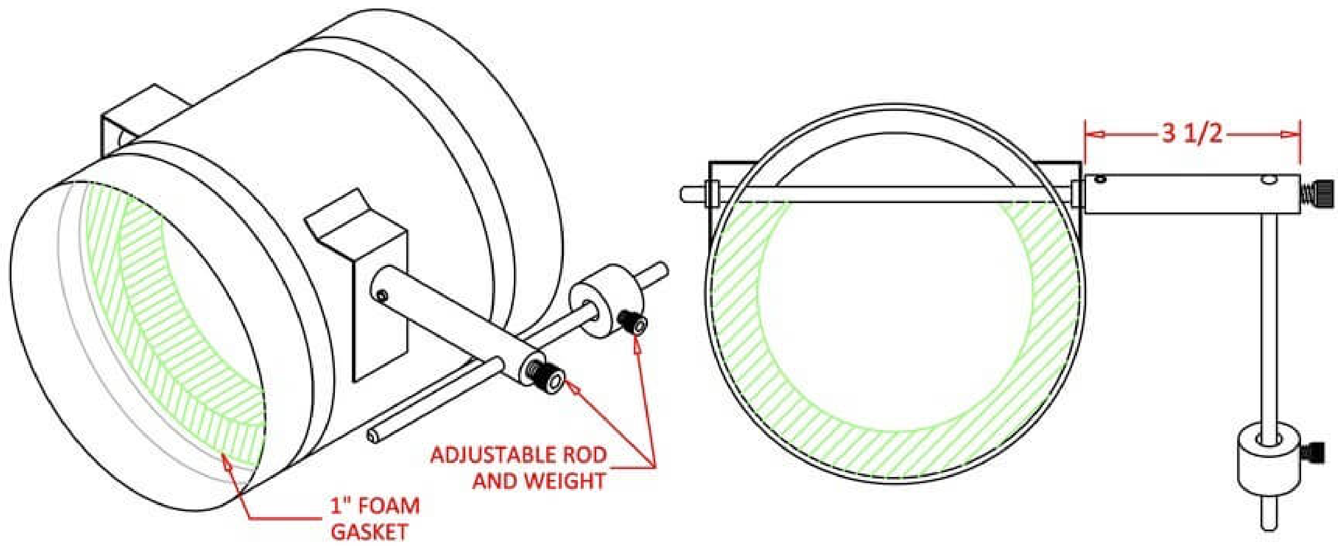
TODO:

- Build Pressure relief valve
- Build Pressure Control valve (5lb 2 T)
- Build Manometer with sliding scale in the middle for evaprotation
- Contents Manometer is distilled water and food coloring

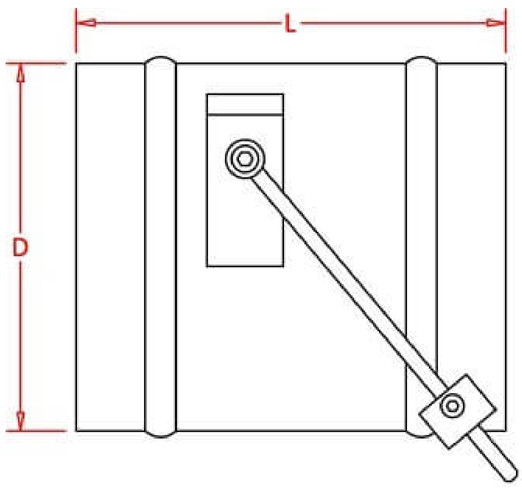
Possible Alternatives

- Poopet Valve

basic gravity valve



PRESSURE RELIEF DAMPER					
ITEM #	SIZE (IN)	D	L	DAMPER ROD	FREE AREA IN^2
PRD5	5	4 7/8	6	6 3/8	8.95
PRD6	6	5 7/8	7	7 3/8	15.03
PRD7	7	6 7/8	8	8 3/8	22.69
PRD8	8	7 7/8	9	9 3/8	31.92
PRD10	10	9 7/8	11	11 3/8	69.03
PRD12	12	11 7/8	13	13 3/8	84.54
PRD14	14	13 7/8	15	15 3/8	120.27
PRD16	16	15 7/8	17	17 3/8	162.29
PRD18	18	17 7/8	19	19 3/8	210.59
PRD20	20	19 7/8	21	21 3/8	265.17



source

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