



MRI STIMULI DELIVERY SYSTEM

User Manual

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1.) Introduction

1.1) Purpose

The purpose of this guide is to provide users of the MRI Stimuli System with a comprehensive overview of the system and how to operate its various components.

1.2) Scope

The scope of this guide includes detailed schematics of the system, a bill of materials for ordering new parts, an in-depth overview describing the function of each component of the system, and a step by step guide to system operation. The guide is meant to be read from start to finish initially to provide the user with fundamental knowledge of the system's inner workings. However, it can also be used as a quick reference guide for operating the system, maintaining components, and troubleshooting any issues that may occur.

2.) General Information

2.1) System Layout

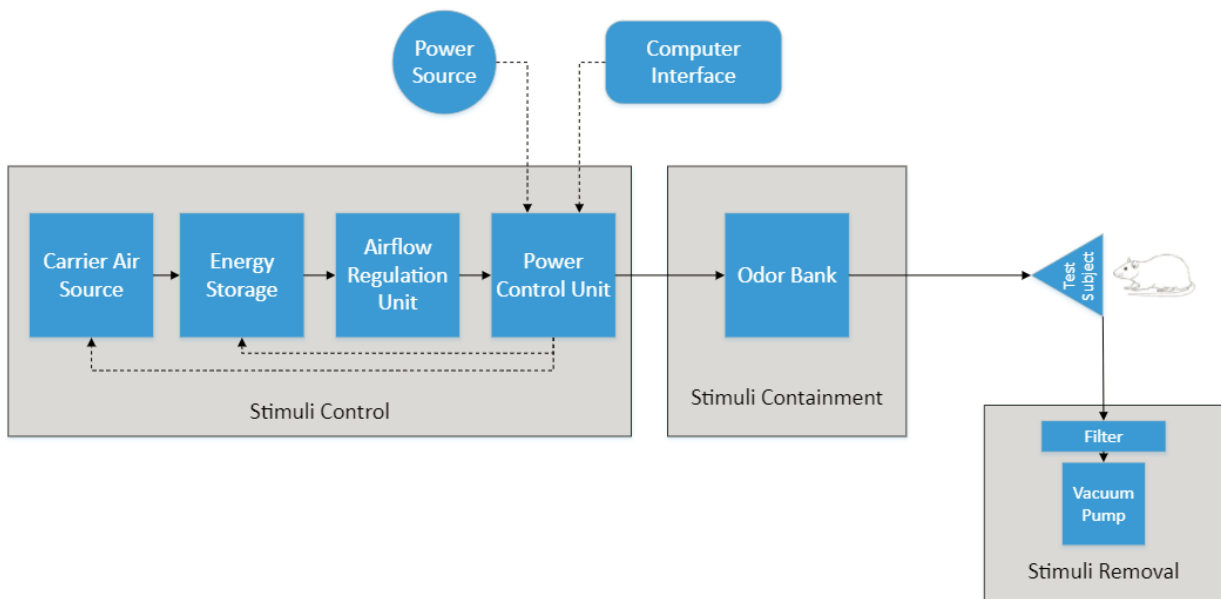


Figure 1: Block diagram of the stimuli delivery system

The MRI Stimuli Delivery System is divided into three phases: stimuli control, stimuli containment, and stimuli removal as shown in Figure 1. The stimuli control portion of the system includes 4 primary components comprised of a carrier air source (compressor), energy storage unit (air tank), air flow regulation unit, and power control box. The stimuli containment phase of the system includes individual odor containment units (centrifuge tubes) as well as an odor bank to store and organize the tubes. Lastly,

the stimuli removal portion of the system is comprised of a dual HEPA and activated carbon filter connected to a vacuum pump at the end of the system. Additionally, a 12V power source must be connected to the power box and a computer interface is used to control operation of the system.

As displayed in Figure 2, airflow begins in the compressor which sends air to the air tank for storage and later usage. Air pressure is maintained at 40-80 psi within the tank by a relay and pressure switch on the tank to provide for an optimal compressor duty cycle. Once the manual flow handle on the tank is opened, air flows to the air regulation unit comprised of a flow regulator and a flow meter. These two pieces of equipment allow the user to fine tune the flow rate of the air before it enters the solenoid valves situated on the control box. Controlled by an Arduino board and graphical user interface

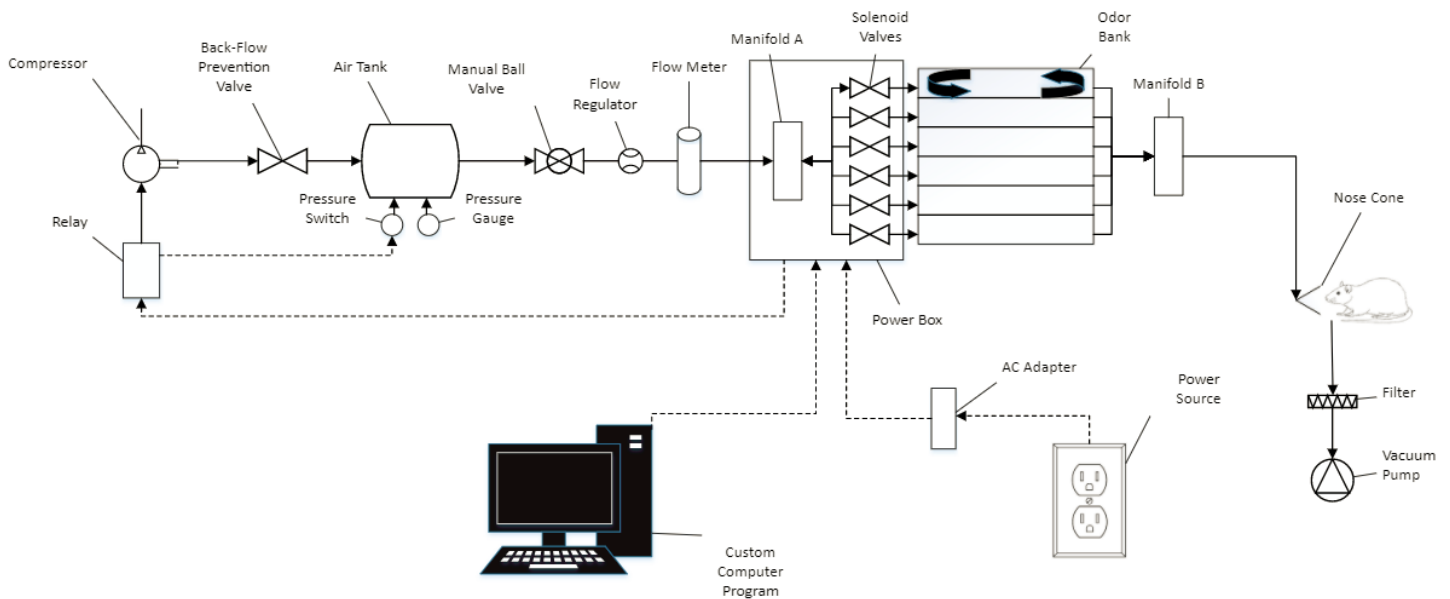


Figure 2: Detailed system layout

(GUI), these solenoid valves can divert the flow of air down any one of five lengths of tubing. The first four lengths of tubing lead to the four stimuli containment units (centrifuge tubes) while the last length of tubing is reserved for fresh air to purge the system.

Once a length of tubing has been selected, the air will flow into the odor containment phase of the system where an odor bank is used to hold four centrifuge tubes filled with liquid stimuli. The air will flow down to the bottom of the tube and bubble up through the liquid impregnating it with the stimuli. From there, the odor laden air will enter a second centrifuge tube that will collect any liquid stimuli that may have escaped the first tube. After this, the air continues on down the tube and is delivered to the test subject via a nose cone inserted into the bore of the MRI magnet.

Once delivery has been executed, the stimuli will be purged from the test subject's environment through the stimuli removal portion of the system. This part of the system begins with a length of tubing situated at the exit of the nose cone. From the nose cone, air is gently suctioned out by a vacuum pump through a dual HEPA and activated carbon filter that neutralizes deleterious stimuli. After the air passes through the filter and the pump, it is dispelled outside of the MRI room to reduce the risk of stimuli re-entering the test subject's environment.

2.2) Bill of Materials

Tubing:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
3/16" ID x 5/16" OD x 1/16" Wall Versilon™ PTFE Tubing	58054	US Plastics	\$48.10 for 10 ft	40 ft	\$192.4
3/16" ID x 1/4" OD x 1/32" Wall Tygon® Sanitary Silicone Tubing	57293	US Plastics	\$18.30 for 10 ft	30 ft	\$54.90

Compressor/ Tank System:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
Air compressor, 12 volt, 0.88 cfm	Am-2005	AndyMark	\$69.00	1	\$69.00
E Support™ Car Truck Motor Heavy Duty 12V 40A SPST Relay Socket Plug 4Pin 4 Wire Waterproof Seal		Amazon	\$7.19	1	\$7.19
Air Hose, 200 PSI with 1/8 x 1/8 NPTF Brass Male Fittings, 200 PSI, red, 2 foot long	1593N45	McMaster Carr	\$5.98	1	\$5.98
Compact Backflow-Prevention Valve, for Water and Inert Gas, 1/4 NPT Female x 1/4 NPT Male	7768K22	McMaster Carr	\$10.42	1	\$10.42
Brass On/Off Valve with Lever Handle, 1/4 NPT Female x 1/4 NPT Male	47865K41	McMaster Carr	\$9.29	1	\$9.29
Vixen Horns VXT1500 6 Ports Train/Air Tank		Amazon	\$54.95	1	\$54.95

System/Kit 150 Psi with Gauge, Pressure Switch, Drain and Safety Valve, 1.5 gal, 5.6 L					
Vixen Horns 1/4 NPT Male to 1/8 NPT Female Brass Thread Reducer Fitting for Train/Air Horn Tanks - Bundle of two fittings VXA1418-2		Amazon	\$7.95 for a pack of two	1 pack	\$7.95
Push-to-Connect Tube Fitting for Air, Straight Adapter, for 5/16" Tube OD x 1/4 NPT Male	5779K113	McMaster Carr	\$5.35	2	\$10.70
Air Compressor Pressure Switch; Range: 25 to 160 psi, Port Type: (1) Port, 1/4" FNPT	3EYP3	Grainger	\$13.30	1	\$13.30

Air Flow Control:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
Scratch-Resistant Acrylic, 12" x 24" x 1/4" White	8505K755	McMaster Carr	\$19.93	1	\$19.93
Compact Compressed Air Regulator (0-25 psi range), Relieving, Aluminum Housing, 1/8 NPT	6763K81	McMaster Carr	\$43.21	1	\$43.21
Cole-Parmer Polycarbonate Flowmeter, 0.4-5 LPM, Air Stainless Steel, w/ Valve	EW-32900-46	Cole-Parmer	\$70.00	1	\$70.00
Mounting Bracket for 1/8 and 1/4 NPT FRL	6763K21	McMaster Carr	\$8.44	1	\$8.44
Galvanized Steel Corner Bracket, 1-3/8" x 1-3/8" x 2.75"	17715A73	McMaster Carr	\$2.55	1	\$2.55
Push-to-Connect Tube Fitting for Air, Long 90 Degree Elbow, for 5/16" Tube OD x 1/8 NPT Male	5779K188	McMaster Carr	\$10.88	3	\$32.64
Push-to-Connect Tube Fitting for Air, 90 Degree	5779K25	McMaster Carr	\$4.41	1	\$4.41

Elbow Connector, for 5/16" Tube OD					
Push-to-Connect Tube Fitting for Air Straight Adapter, for 5/16" Tube OD x 1/8 NPT Male	5779K112	McMaster Carr	\$5.35	1	\$5.35
6061 Aluminum 3/4" Thick x 3" Wide x 6" Long	8975K231	McMaster Carr	\$12.35	1	\$12.35

Manifolds:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
Straight-Flow Rectangular Manifold, 6 Outlets, 1/4 NPT Inlet x 1/8 NPT Outlet	1023N14	McMaster Carr	\$30.27	2	\$60.54
316 Stainless Steel Threaded Pipe Fitting, Low-Pressure, Plug with External Hex Drive, 1/8 NPT	4452K141	McMaster Carr	\$2.50	2	\$5.00
Push-to-Connect Tube Fitting for Air, Straight Adapter, for 5/16" Tube OD x 1/4 NPT Male	5779K113	McMaster Carr	\$5.35	2	\$10.70
Push-to-Connect Tube Fitting for Air Straight Adapter, for 5/16" Tube OD x 1/8 NPT Male	5779K112	McMaster Carr	\$5.35	10	\$53.50

Control Box:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
Scratch-Resistant Acrylic, 12" x 24" x 1/4" White	8505K755	McMaster Carr	\$19.93	1	\$19.93
LED wholesalers 12V 20A 240W AC/DC Power Adapter with 5.5x2.5mm DC Plug and 2.1mm Adapter, Black, 3262-		Amazon	\$39.99	1	\$39.99

12V, 12 volt, 20 amp, 55" long					
ARDUINO MEGA 2560 REV3	A000067	Arduino	\$38.50	1	\$38.50
AmazonBasics USB 2.0 Cable - A-Male to B-Male - 6 Feet (1.8 Meters)		Amazon	\$4.99	1	\$4.99
SainSmart 16-Channel Relay Module		Amazon	\$19.29	1	\$19.29
HOSL DC 12V 1/4 Inch Electric Solenoid Valve for Air Water / Replacement Brass Valve for Use with Pipelines in Water, Air and Diesel Applications		Amazon	\$10.99	5	\$54.95
Push-to-Connect Tube Fitting for Air, Straight Adapter, for 5/16" Tube OD x 1/4 NPT Male	5779K113	McMaster Carr	\$5.35	10	\$53.50
Miniature Toggle Switch, 2 Position, 1 Circuit, Maintained, solder lugs	7347K75	McMaster Carr	\$7.86	2	\$15.72
LED - Basic Red 5mm	COM-09590 ROHS	Sparkfun	\$0.35	6	\$2.10
LED - Basic Green 5mm	COM-09592 ROHS	Sparkfun	\$0.35	2	\$0.70
Resistor 330 Ohm 1/6 Watt PTH	COM-11507 ROHS	Sparkfun	\$0.95 for a pack of 20	1	\$0.95
Resistor 1K Ohm 1/4th Watt PTH	COM-13760 ROHS	Sparkfun	\$0.95 for a pack of 20	1	\$0.95
E Support™ Car Truck Motor Heavy Duty 12V 40A SPST Relay Socket Plug 4Pin 4 Wire Waterproof Seal, 12V 40A Relay		Amazon	\$7.19	1	\$7.19
Gdstime Slient 5 Volt 50mm x 50mm x 10mm 2 Inch 0.14A Mini Brushless Cooling fan		Amazon	\$8.99	1	\$8.99

Mortise-Mount Hinge with Nonstandard Hole Pattern, Removable Pin, Square, Zinc-Plated Steel, 1" x 1/2" Leaves	1597A41	McMaster Carr	\$0.82	4	\$3.28
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Odor Bank:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
Clear Ultra-Scratch-Resistant Acrylic, 12" x 24" x 1/4" Clear	8536K162	McMaster Carr	\$53.53	1	\$53.53
Clear Ultra-Scratch-Resistant Acrylic, 12" x 24" x 1/8" Clear	8536K132	McMaster Carr	\$38.84	1	\$38.84
Scratch-Resistant Acrylic, 12" x 24" x 1/4" White	8505K755	McMaster Carr	\$19.93	1	\$19.93
7/8 in. White Spring Grip	Internet #202305505	Home Depot	\$2.58	8	\$20.64
50mL Centrifuge Tubes	TC5000R	Argos	\$146.18 for a pack of 25	1 pack	\$146.18
Oil-Resistant Buna-N O-Ring, 1/16 Fractional Width, Dash Number 047, Fractional ID: 5/16, fractional OD: 1/2	9464K44	McMaster Carr	\$5.04 for a pack of 50	1 pack	\$5.04
Oval Grip Pull Handles with Unthreaded Through Holes, Zinc-Plated Steel, 4-1/8" Center-to-Center Width	1646A13	McMaster Carr	\$2.07	3	\$6.21
LEXAN, 12 in. x 24 in. x .093 in. Clear Polycarbonate Sheet	Internet #202038063	Home Depot	\$15.98	2	\$31.96

Test Subject Interface:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
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Funnel PTFE 30 x 50 mm	342325-0050	Dynalon	\$24.52	1	\$24.52
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Evacuation System:

Part Name	Part Number	Manufacturer/Supplier	Unit Price	Quantity	Total Price
Oil-Resistant Buna-N O-Ring, 1/16 Fractional Width, Dash Number 047, Fractional ID: 4 1/2, fractional OD: 4 5/8	9452K312	McMaster Carr	\$4.90 for a pack of 10	1 pack	\$4.90
DC 12V micro air pump Electric pumps mini vacuum pump pumping Booster For Medical		Amazon	\$8.99	1	\$8.99
WSTA Desktop Air Purifier, Air Ionizer ,Portable Air Purifier, True HEPA Air Cleaner Replacement Filter for W050, W050D, W050S, W050T		Amazon	\$10.99	1	\$10.99

Total Cost = \$1,407.46.

3.) System Overview

3.1) Compressor & Air Tank

The operation of the device begins with the compressor/tank system shown in Figures 3A and 3B, which are responsible for pressurizing and storing the air to be used in the system. This section will explain how to operate these two components and identify the order in which they should be controlled to properly deliver air to the system.

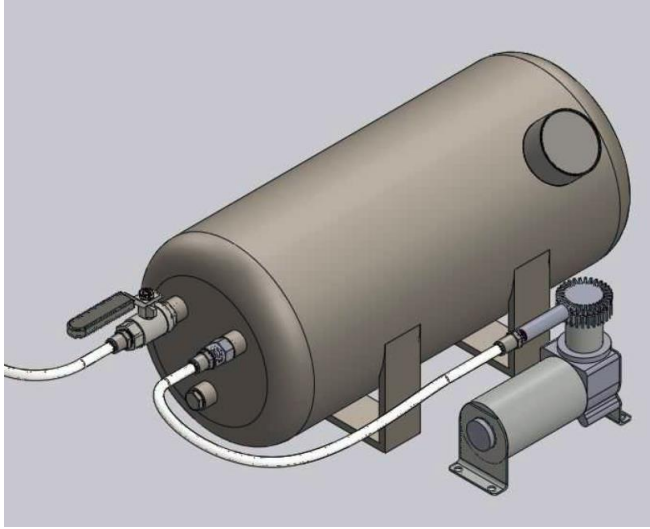


Figure 3A: SolidWorks model of compressor and air tank



Figure 3B: Fully assembled compressor and air tank

3.1.1) Component Description

The tank and compressor, shown in Figure 4, form a system which receives power through the same source as the rest of the device, a 12-V adapter that can be plugged into a wall outlet. The air tank itself has a capacity of 1.5 gallons, which is capable of pressurizing to a maximum of 250 psi, although it is recommended to operate under 125 psi. The tank is required due to its ability to initiate a choked-flow situation, where air flow is delivered to the rest of the system at a continuous flow rate due to the pressure established within the tank and its relationship to the pressure being drawn

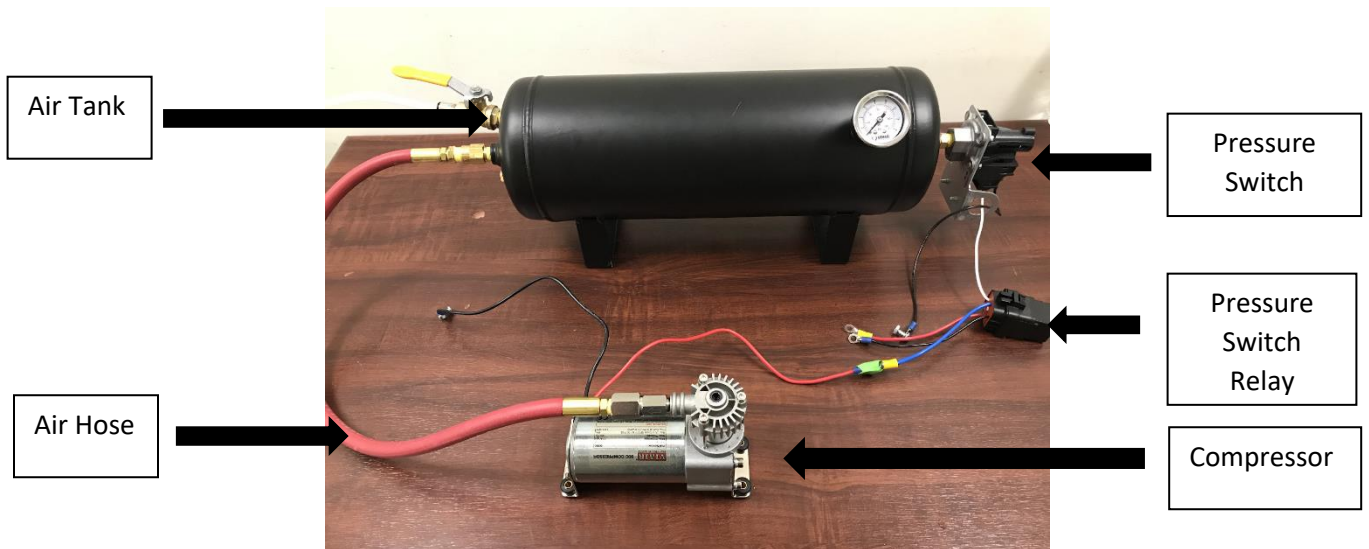


Figure 4: The tank and compressor system complete with pressurized connecting hose and pressure switch with relay

from the flow control unit. Without a tank or similarly pressurized storage unit, a

compressor would deliver air at a fluctuating flow rate and would be operating constantly, which produces a large amount of heat and noise.

The compressor is oil-less, which reduces the chance for waste vapors and volatiles entering the delivered air stream, and it is recommended that if the compressor is replaced by an oil lubricated compressor or similar device, that a filter is used to clean the air before it enters the tank. The compressor is connected to the tank through a pressurized hose which attaches with 1/8" to 1/4" female to male fittings. A backflow prevention valve is included in the hose to tank connection to prevent any air from flowing back towards the compressor.

A pressure switch connects the tank and compressor and is responsible for reading the pressures within the tank and adjusting the compressor accordingly. The pressure switch is currently set to activate the compressor when the air tank reaches 40 psi or less and turns the compressor off when the tank is filled to 80 psi. Subsection 3.1.3 details the process of adjusting these pressure settings. This functionality allows the compressor to operate intermittently on its duty cycle, thus mitigating any component damage that might occur from running the compressor continuously.

3.1.2) Component Operation

1. Plug in the components to supply power.
2. If the tank's pressure is below the cutoff pressure, the compressor will automatically turn on at this point.
 - a. Turn the yellow valve handle connecting the tank output nozzle to the flow control unit so that it is perpendicular to the tank, as seen in Figure 5A. This closes the nozzle and prevents air from flowing.
 - b. Allow the tank to be filled to the cutoff pressure established by the pressure switch.
 - c. The compressor will automatically turn off at this point.
3. Next turn the yellow valve handle from step 2a to the parallel position, as seen in Figure 5B, to allow air to flow to the rest of the system.
4. During the test, when the tank reaches the low pressure established by the pressure switch, the compressor will automatically turn on to fill it up without disrupting the test or changing the flow rate.



Figure 5A: Yellow valve handle perpendicular to air tank in the closed position

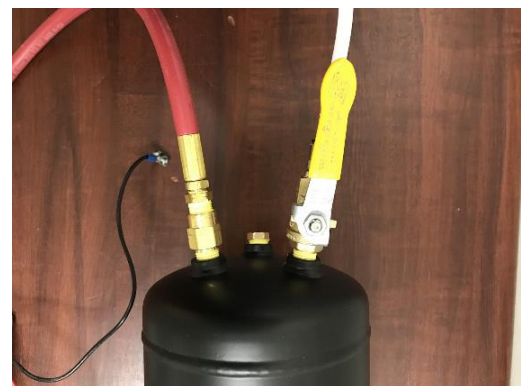


Figure 5B: Yellow valve handle parallel to air tank in open position

5. The compressor will automatically turn off when the tank pressure reaches the cutoff pressure established by the pressure switch.
6. At the end of the testing sequence, it is recommended to empty the tank by unplugging the system from power and moving the output valve to the parallel position.

3.1.3) Changing the Pressure Switch

For some experiments, or if you decide to use a different tank in the system, the cutoff and cut-on pressures for the device may need to be adjusted. To do this, the pressure switch can be altered. There are two screws located on the underside of the pressure switch, as seen Figure 6 below. The top screw can be turned clockwise to increase the cutoff pressure value. This value corresponds to the maximum pressure needed in the air tank, or the pressure of the air tank that will cause the compressor to turn off. The bottom screw can be turned clockwise to increase the pressure differential. The pressure differential is the value that determines the cut-on pressure, or the pressure at which the compressor will turn on, based on the cutoff pressure. It is simply subtracted from the cutoff pressure to determine the cut-on pressure. For example, if the cutoff pressure is set to 80 psi, and the pressure differential is set to 25 psi, then the compressor will turn on to start filling the tank up at 55 psi.

Unfortunately, the screws do not have units or numbers during this adjustment process, so you will likely have to adjust the screws and then turn on the system to see when the compressor turns on and off. It is recommended that during this process, only one screw is changed at a time.

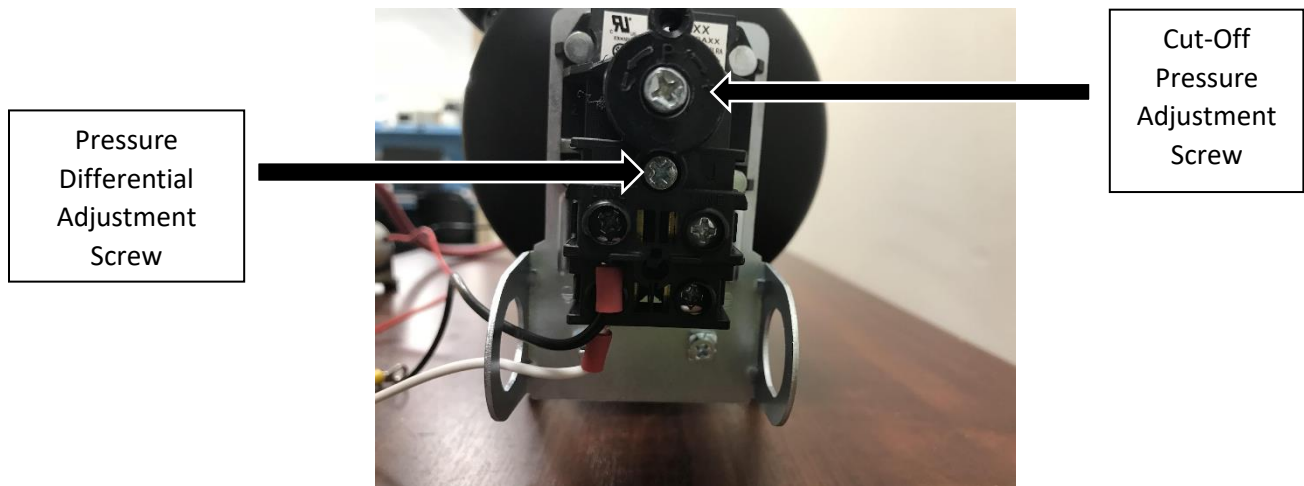


Figure 6: This diagram shows the pressure switch screws. The top screw is used to adjust the cutoff pressure, while the bottom screw is used to adjust the pressure differential

3.2) Air Flow Regulation Unit

The air flow regulation unit is responsible for accurately controlling the flow rate of the air being introduced into the liquid stimuli of the odor bank. As the air flow rate and concentration of odor delivery is directly correlated, this portion of the system is crucial to accurate stimuli delivery to the test subject.

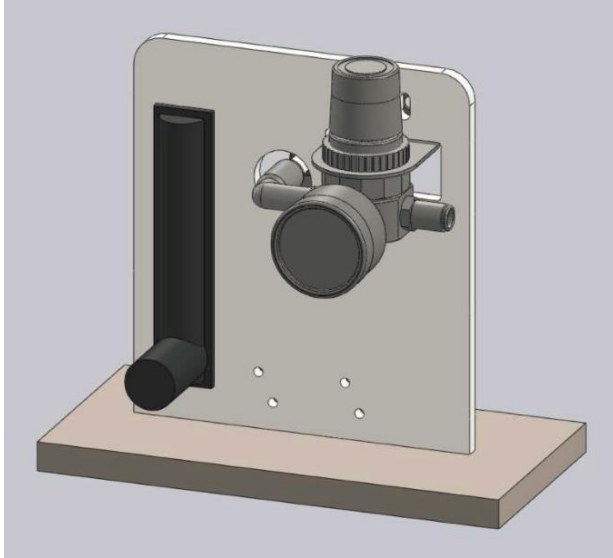


Figure 7A: SolidWorks model of airflow regulation unit



Figure 7B: Fully assembled airflow regulation unit

3.2.1.) Component Descriptions

The air flow regulation unit consists of a McMaster-Carr pressure regulator and a Cole-Farmer polycarbonate flow meter mounted to an acrylic stand and aluminum base as seen in Figure 7B. PTFE tubing from the air tank output is connected to the pressure regulator via a push-to-connect fitting. The pressure regulator is in turn connected to a flow meter which then leads on to manifold A. The pressure regulator allows for pressure adjustment within the range of 0-60 psi and the flow meter allows for flow rate adjustment from 0-5 L/min.

3.2.2) Component Operation

By turning the knob on the top of the pressure regulator, the user can set the output air pressure to a range of 0-60 psi.

1. First pull upwards on the knob until it pops out of the lock position and into the adjustment position
2. The knob can then be turned clockwise to increase air pressure and counter-clockwise to decrease air pressure
3. By adjusting the air pressure passing through the regulator, the user can create an approximate flow rate that leads to the flow meter for additional fine tuning.
4. Push the knob back down when complete to lock it back into place

With an appropriate air pressure leading to the flow meter, the user can then adjust the flow rate. To do this, simply locate the control knob on the bottom of the flow meter and turn it clockwise to reduce the flow rate and counter-clockwise to increase the flow rate.

3.3) Power Control Box

The control box, which can be seen in Figures 8A and 8B, is the portion of the device responsible for housing the electrical components which allows the system to be automated. The control box itself is made from laser-cut acrylic and assembled using acrylic glue. A waveform pattern and fan are installed to cool internal components through air circulation, and hinges allow for easy access to the interior of the box.

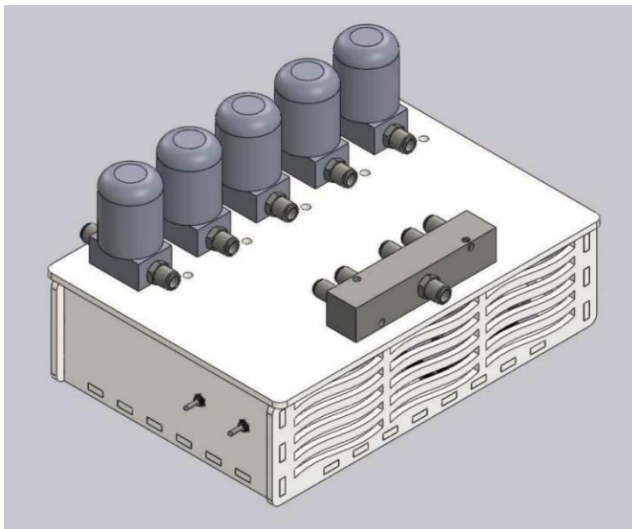


Figure 8A: SolidWorks model of power control box



Figure 8B: Fully assembled power control box

3.3.1) Component Description

Within the control box lie several components that help to control the automation of the device. If you are not confident in circuitry or wiring electronics, it is suggested to ask an expert to make any required changes. As seen in Figure 9, the components included in the interior of the control box are an Arduino Mega, a relay module, a relay, a power switch and run test switch, and a fan.

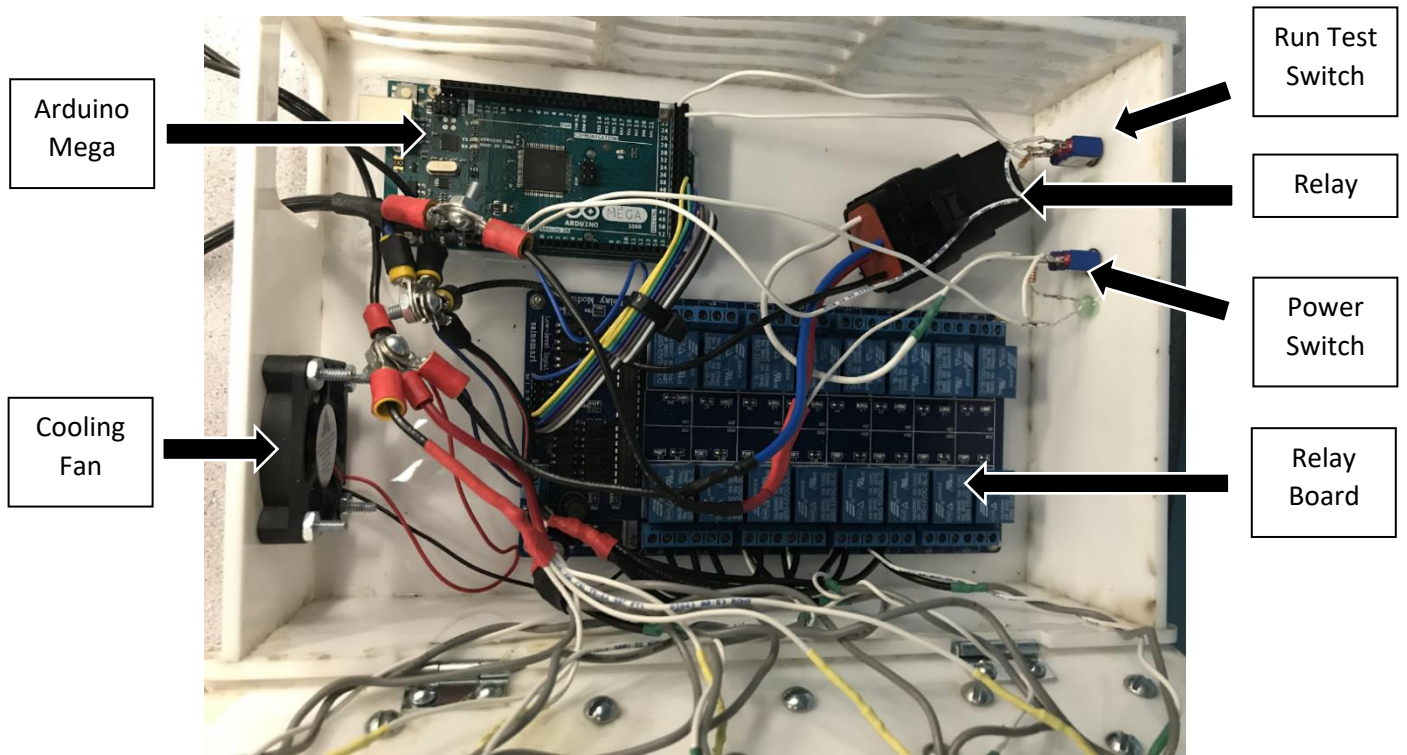


Figure 9: This image shows the interior components of the control box with the most important components labeled

The Arduino Mega is a microprocessor and control board which can run custom-made code to manipulate electronic objects. This device is where you will connect your computer with a USB cable to upload any code for testing alterations. The 16-channel relay module adds additional space to control and interface with more devices than the Arduino Mega can offer alone. They essentially work in tandem to control the rest of the electrical components in the device. The relay acts as an electrical switch which completes certain circuits when power is supplied, and closes circuits when power is not supplied. The run test and power switches mark the interior portions of the labeled switches on the exterior of the control box. They are both accompanied with green LEDs to mark whether or not they have been turned on. The fan is connected to power so that it is turned on as soon as power is delivered to the device so that it can circulate air and cool the internal components.

3.3.2) Circuit Diagrams

In the case of any components getting unplugged or destroyed, these circuit diagrams provide the necessary information for re-wiring the circuitry that we have provided. Additionally, Figure 9 shows the wiring at a more macroscopic view so that both can be followed when wiring the control box. Figures 10, 11A, 11B, and 12 below contain these circuit diagrams with brief captions for more information.

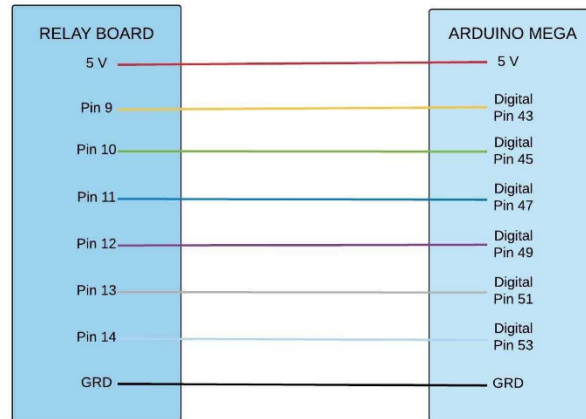


Figure 10: This diagram shows the connections between the Arduino Mega and the relay board. These connections show a straightforward ground to ground and 5V power to 5V connection with the rest of the wires simply connecting pins from the Arduino to those of the relay board

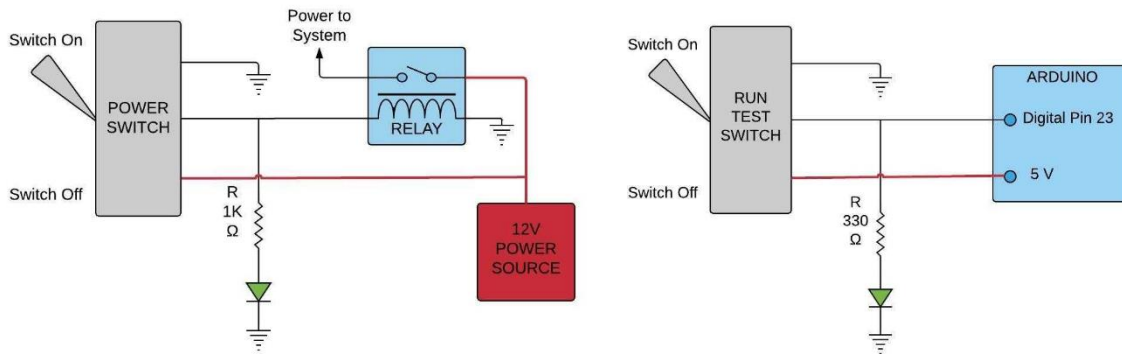


Figure 11A & 11B: The diagram on the left shows how the power switch completes a circuit when on, and how that circuit is then disconnected when the flip is switched off. The diagram on the right shows the same configuration for the run test switch. The dashed lines of descending width forming a triangle represent connections to ground, and jagged lines represent resistors, with labeled resistances. The power switch is connected to the power source and the relay, which allows the switch to power on the rest of the system when it is flipped. The run test switch is connected to the Arduino

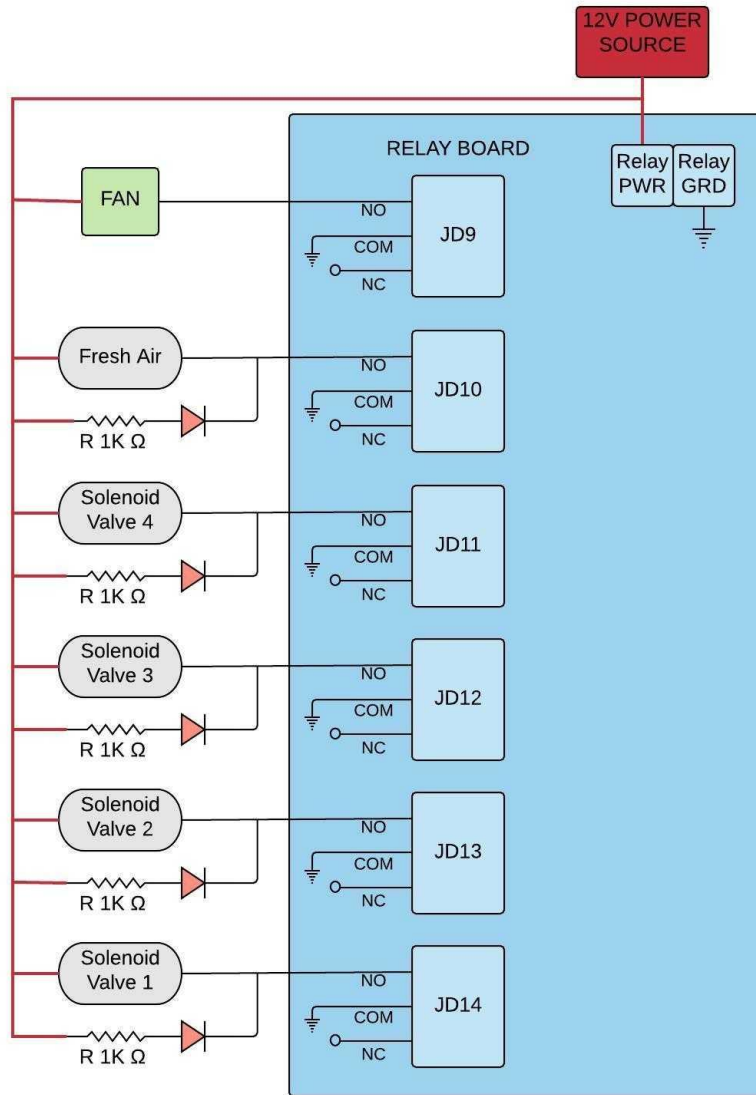


Figure 12: This diagram details the connections made on the relay board itself. Relay power is connected to the 12V power source used by the entire system, and the rest of the connections are to the fan and the solenoid valves. Because the relay board is connected to the Arduino (seen in Figure 10), when the program is loaded into the Arduino, it then communicates with the relay board and instructs it to open and close specific solenoids. Additionally, the fan is connected to the relay, and is instructed by the Arduino to be powered on for the duration of system operation

3.3.3) Component Replacements

If any of the components break or otherwise need replacement, it is suggested that you follow the circuit diagrams to reconnect them. The bill of materials in Section 2.2 details the components used so that you can buy the exact models as used in the original device. If wires are damaged, any conductive wire with a sheath that can fit in the Arduino pins can be used. Otherwise, the component most likely to need replacement in this portion of the device are the LEDs used to mark when the switches and solenoids have been

activated. These LEDs are cheap and easy to find, but need to be soldered with the coupling resistor and the ground connection to ensure that they remain in place and powered properly. In order to solder these components, a soldering iron and some solder material (filler metal than can be easily melted) will be needed. Additionally, the LEDs connected to the power switch and run test switch are glued into the control box to ensure that they are visible to the test operator.

3.4) Odor Bank

The odor bank of the stimuli delivery system is responsible for safely holding and containing stimuli used in testing. It has been specifically designed to incorporate the maximum degree of flexibility with user safety.

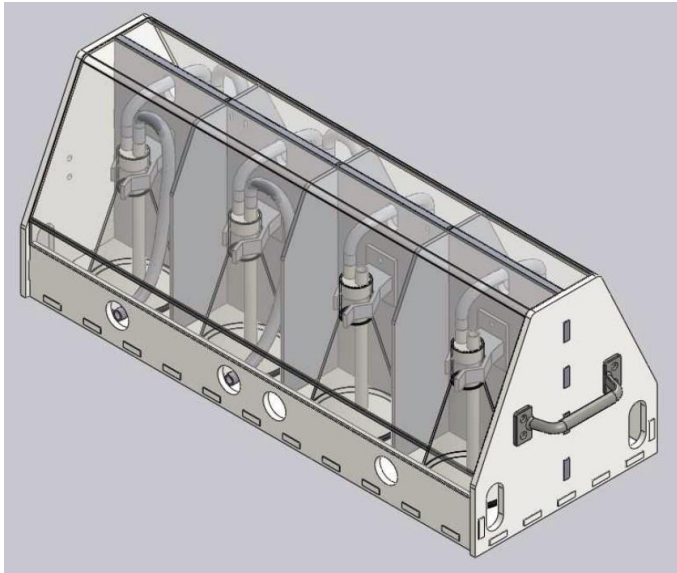


Figure 13A: SolidWorks model of odor bank



Figure 13B: Fully assembled odor bank

3.4.1) Component Description

As seen in Figures 13A and 13B, the odor bank is composed of a 20" by 8" rectangular acrylic base with two 8" tall hexagonal acrylic supports on each end of the base. Surrounding the base there is a 2" high lip to prevent liquid stimuli from spilling out onto the work bench if it escapes the centrifuge tube. Down the middle of the odor bank, there is a transparent acrylic center support that is attached at each end to the hexagonal end pieces. Mounted to the center support are 4 Everbilt brand spring grips screwed in at 5" intervals. This first set of spring grips holds the liquid stimuli and on the other side of the center support, a second set of 4 spring grips holds empty centrifuge tubes to collect any escaped liquid stimuli. To provide additional reinforcement to the center support, hexagonal upright pieces of transparent acrylic are attached between the spring grips. An added benefit of these uprights is that they semi-compartmentalize the

stimuli-containing centrifuge tubes to help prevent cross contamination. To complete the design, handles were added to the side of the odor bank for portability and a Lexan polycarbonate lid was crafted to protect the system users from any potential stimuli splashes or tube ruptures.

3.4.2) Component Operation

1. To set up the odor bank, fill up the first set of centrifuge tubes with the desired amount of stimuli and place them in the first set of spring grips
2. Next, insert the specially curled PTFE tubing into each of the centrifuge tubes and place the other end into the appropriate solenoid on the power box
3. Then insert a second set of empty centrifuge tubes on the other side of the center support and connect the two sets with the horseshoe shaped tubing pieces
4. After, insert the specially curled tubing into the second set of centrifuge tubes and connect the other ends to manifold B
5. With the centrifuge tubes set up and connected, the user can then place the polycarbonate lid over the entire odor bank for added protection.

3.5) Evacuation System

The evacuation system is responsible for removing contaminants and hazardous particles from the system through the use of a filter. Clean air is then released back into the lab area. This section will explain how to operate the components of the evacuation system and explain how often parts should be replaced.

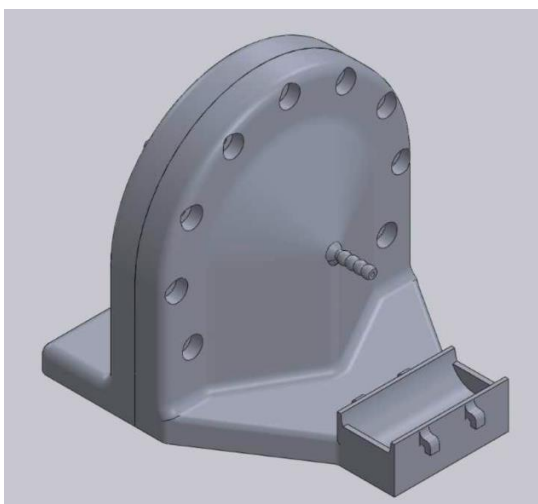


Figure 14A: SolidWorks model of filter adapter

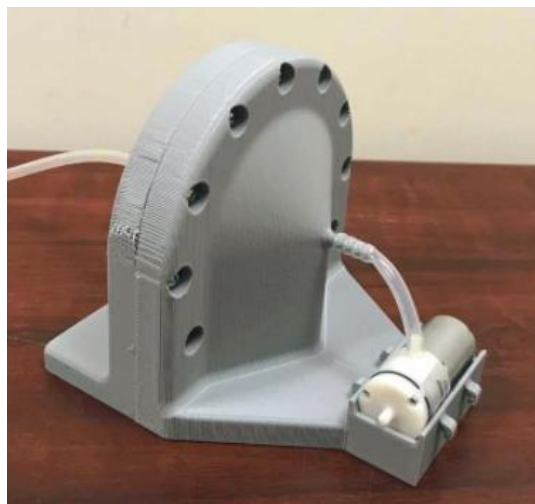


Figure 14B: Fully assembled filter adapter

3.5.1) Component Description

The evacuation system, shown in Figures 14A and 14B, consists of evacuation tubing, an adapter, the filter, and exit tubing. During testing suites, the evacuation system must be kept in the testing room away from the MRI, as it contains metal screws. Evacuation tubing of the device consists of a length of PTFE tubing. The length of the

tubing largely depends on the dimensions of the testing and operating rooms, as the tubing begins at the nose cone and travels from the operation room to the testing room where the evacuation system is placed. The adapter is 3D printed out of two pieces of PLA that are secured together using seven 8-32 bolts. The two separate pieces are labeled A and B in order to distinguish between the two. Within the adapter, a replacement filter as seen in Figure 15 manufactured by WSTA for models W050, W050D, W050S, and W050T is used to filter out unwanted contaminants. The filter has a circumference of 3.93 inches and a depth of 0.67 inches and contains a HEPA filter and an activated charcoal filter, enabling it to filter out 99% of particles that have a size greater than or equal to 0.3 micrometers. The filter is secured into place using grooves on the adapter, and an O ring is also included to ensure a snug fit. The exit tubing provided is made out of silicone, but any type of tubing that fits onto the adapter can be used. The length of this tubing also depends on the dimensions of the testing room.

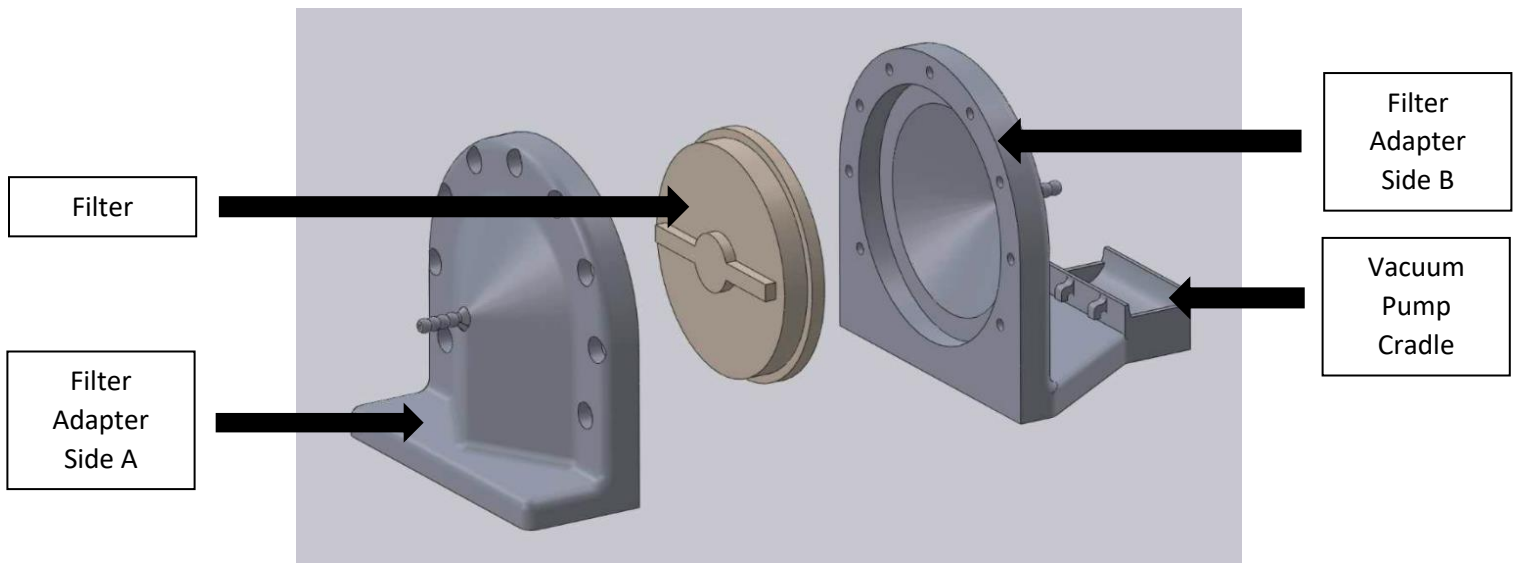


Figure 15: Exploded view of filter adapter and filter

3.5.2) Component Operation

1. Push the O-ring into the small groove on side A of the filter adapter
2. Place the filter into side B of the filter adapter such that it rests in the circular inset as seen in Figure 15
3. Firmly press side A and B of the adapter together and bolt them in place using seven nuts and bolts.
4. Secure the evacuation tubing onto the male fitting of side A
5. Secure the exit tubing onto the male fitting of side B and then connect the other end of the tubing to the vacuum pump as shown in Figure 14B

3.6) Computer Interface

3.6.1) Working with the Arduino Program

The simple graphical user interface (GUI) that you will use to interact with the automated aspects of the device was written with the Arduino programming language, which is based in C++. In the flash drive that we supplied you with, there is a file titled “Solenoid_Control_1” which can be loaded into the Arduino IDE, which can be downloaded on any computer for free by clicking on the following link and selecting your computer’s operating system:

<https://www.arduino.cc/en/Main/Software>

When loading the program into the Arduino IDE, you are able to change any of the parameters to better match your testing requirements. It is suggested that you save a master copy of the program so that you have a backup if any changes render the program inoperable.

Since many of the variables of the program are altered by the test operator during the testing sequence through input, you likely do not have to change anything in the program directly. However, if you require tests that involve more than 20 delivery sequences (more than 20 times the “What number vial would you like to use” prompt is answered), the array used to store that information will need to be expanded. This array is called vialDeliveryNums and is located towards the beginning of the program. Currently, it is an array that can hold 20 pieces of information, but this can be expanded by changing the 20 (in the square brackets) to a larger number that you require.

After working with and changing the Arduino program, hit the check mark button in the top left corner to verify the code. This process will print warning statements if there is anything wrong with the program. If the program does not contain any errors, it can then be uploaded by clicking the horizontal Upload arrow button located next to the Verify button. In order to upload the altered code to the Arduino, the Arduino and computer containing the code must be connected through a USB.

3.6.2) Program Flow Chart

To more easily visualize the operational order of the program, Figure 16 below shows the program flow chart.

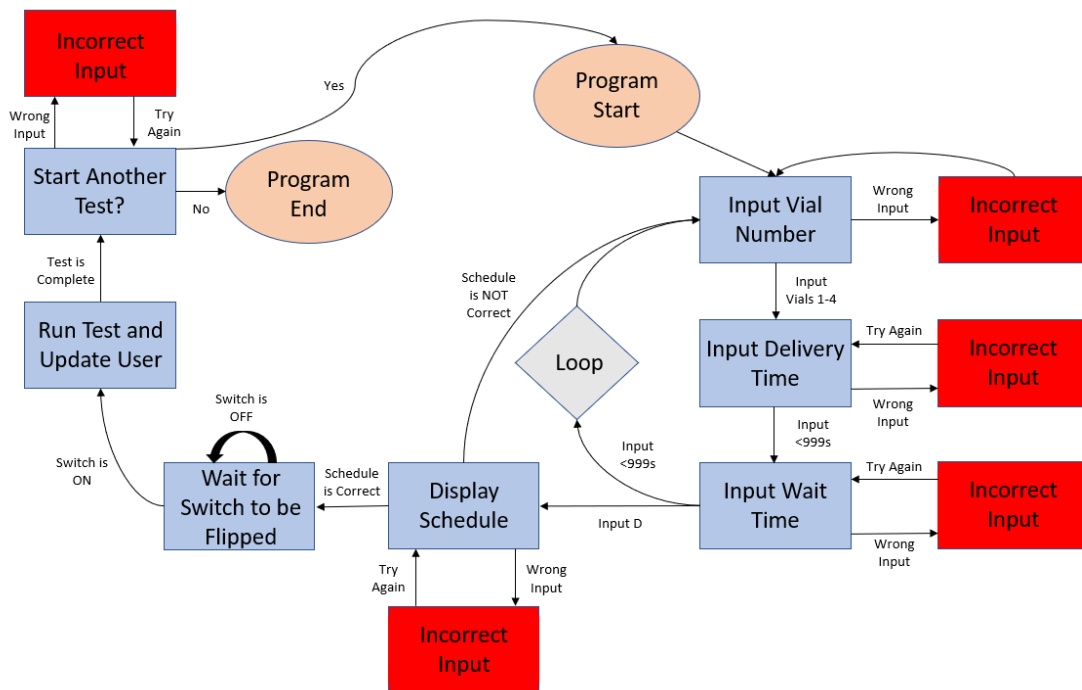


Figure 16: A flow chart of the computer program's testing sequence

The flow chart shows that the entire program runs on a loop for a duration that is determined by the number of vials that the user wishes to use. Additionally, the red boxes indicate that whenever a user enters incorrect input for a specified prompt (i.e. a number when a word is requested, or a length of time over 999 seconds), it will be recognized as incorrect and the user will be prompted to enter something else. The blue boxes represent points of interest in the program, which are usually prompts for the user, or printed instruction statements. The two orange circles represent the program beginning and end, and the gray diamond shows the part of the program that is contained in a loop.

The arrows connecting each portion of the flow chart signify the direction of the flow chart and are often accompanied by some keywords that signify what must have occurred in the previous step to lead down the selected path. For example, there are three arrows stemming from the "Input Wait Time" box, and two arrows leading towards it. The first arrow leading towards it stems from "Input Delivery Time" which means that if an acceptable delivery time is entered at that step (a delivery time of less than 999 seconds), the next step prompts the user to enter a wait time. The arrows stemming from this box all signify a different direction the program can take, depending on the input. If the input is incorrect, the program will warn the user and then ask for a proper wait time again (represented by the line accompanied by "Try Again"). If the user enters an acceptable wait time, they are looped back to being asked for the next vial number, and if the user enters "D" or "d" signifying that they are finished entering information, the program will then display the schedule created by the user.

4.) System Operation

4.1) Set-Up

1. Unpack all of the components from storage and place on a hard flat surface within 7-8 feet of a power outlet (the total length of the power cord from power box to plug is 119 inches).
2. Arrange the components linearly in the following order:
 - a. Compressor
 - b. Air Tank
 - c. Air Flow Regulation Unit
 - d. Power Control Box
 - e. Odor Bank
 - f. Nose Cone
 - g. Filter Adapter Unit
 - h. Vacuum Pump
3. Connect the air tank output to the pressure regulator on the air flow regulation unit with a 1-2 foot piece of PTFE tubing.
4. Connect the flow meter on the air flow regulation unit to manifold A on the power box with a piece of 1-2 foot PTFE tubing.
5. Fill up the first set of centrifuge tubes in the odor bank with the desired amount of liquid stimuli.
6. Connect the solenoid valves on the power box to the first set centrifuge tubes using the specially curled tubing pieces.
 - a. Ensure that the PTFE tubing touches the bottom of the centrifuge tube to allow for proper odor impregnation
7. Connect the first set of centrifuge tubes to the second set of centrifuge tubes using the horseshoe shaped pieces of PTFE tubing.
 - a. Ensure that the ends of the horseshoe shaped tubing in both centrifuge tubes never touches the liquid stimuli and does not go down into the tube more than an inch. This will prevent stimuli in liquid form from entering the downstream tubing and contaminating the system and disturbing the test subject.
8. Attach the second set of centrifuge tubes to manifold B using the specially curled pieces of PTFE tubing
9. Attach manifold B to the nose cone with a length of PTFE tubing cut to fit the distance from manifold B to the bore of the MRI machine
10. Attach an equal length of flexible tubing from the evacuation port of the nose cone to the dual HEPA/activated carbon filter
11. Attach a 3-4 inch length of flexible tubing from the filter adapter to the vacuum pump
12. With the system fully connected, plug in the 12V power cord to the nearest wall outlet.
13. The system is now ready to be powered on for testing.

4.2) System Usage

After the system components have been set up and the power source has been connected, open the control box to find a USB link cable attached to the Arduino Mega.

1. Connect the other end of this cable to the computer which contains the program given to you, or your own custom procedure.
2. Open your program with the Arduino IDE.
3. Go to the “Tools” tab of the tool bar at the top left of the program.
4. Select “Board Manager” and set the type of board to an “Arduino/Genuino Mega or Mega 2560.”
5. Select “Port” and chose the correct port, which will be the USB port connecting your laptop with the Arduino.
6. Compile the program to ensure there are no errors or warnings, then upload this program to the Arduino.
 - a. If the program did not upload, it is possible that the wrong port was chosen, or the Arduino is not properly connected.
7. When the program has been uploaded, follow the command prompts to enter the data concerning the current testing sequence that you would like to run.
8. Keep the Arduino plugged into the computer for the duration of the test to allow test status notifications to be delivered.
9. After the test schedule is confirmed, flip the switch on the control box marked “POWER.” This switch will now deliver power to the system, which will be signified by a green LED lighting up, and the compressor turning on if the pressure in the tank is significantly low.
10. While the tank is being filled ensure that the ball valve is closed. Once the tank has been sufficiently filled, the compressor will automatically turn off.
11. Set the flow rate for that specific test. To do this, open the air output valve on the tank as shown in Figure 5B, and adjust the pressure regulator and then the flowmeter.
12. When the desired flow rate is achieved, you are ready to run the test.
13. The automated system will perform all the necessary actions required to run the test and will update you with information along the way.
14. To start a test, flip the switch on the control box labeled “RUN TEST”.
15. Once the test has finished, you can run a new test or end the sequence.
16. Once done, turn off the “POWER” and “RUN TEST” switches on the control box and unplug the wall power source.
17. After you have finished testing for the day, it is recommended that you change the centrifuge tubes used to store liquid odorants and clean the tubing exposed to odorants by running water through the disconnected tubing until you can no longer smell anything on them.

4.3) Break-Down & Storage

1. To break down the system after testing has been completed, the user must first disconnect the 12V power cord if not already unplugged.
2. Next simply disconnect the following pieces of equipment by pushing in on the outer ring of the push-to-connect fitting and pulling out on the PTFE tubing:
 - a. Air tank output from air flow control unit
 - b. Air flow control unit from power control box
 - c. Power control box from odor bank
 - d. Odor bank from manifold B

- e. Manifold B from nose cone
 - f. Filter adapter from nose cone
 - g. Vacuum pump from filter adapter
3. With all of the components disconnected, it is recommended to wash all PTFE tubing out with fresh water to remove any stimuli or contaminants.
 4. Next, dry all pieces of tubing and tie them into a bundle using rubber bands or wire.
 5. Finally, place all equipment into their respective storage boxes as detailed below:
 - a. Storage Box 1: Compressor, air tank, power control box, 12V power cord
 - b. Storage Box 2: Air flow regulation unit, odor bank, PTFE tubing bundle, centrifuge tubes, filter adapter, vacuum pump
 6. Note: Ensure that the system is stored near room temperature in a dry place. Avoid extreme heat or cold to prevent damage to electrical components.

4.4) System Maintenance

In order to maintain the life of this device, all components should be cleaned after each use and stored in a dry, non-humid environment.

1. To clean the tubing and vials, rinse with water and a small amount of dish soap and then let dry. Ensure that all tubing is dry before use in the device. To adjust the length of tubing, use shears or cutters and ensure that the ends of the tubes are cut perpendicularly to the length of tubing
2. Ensure that corrosive stimuli is quickly washed off the 3D printed caps to avoid damaging them
3. During usage, ensure that the pressure switch is working and the duty cycle of the compressor allows ample time for cool down between operating times
4. Calibrate the pressure switch and flow meter before testing to confirm they have accurate read outs
5. To replace wiring, use a sharp edge to score the heat shrink material and heat the wiring connection with a soldering iron to separate the wires. Before soldering new wires together ensure that you first put new heat shrink material on one end of the wired connection. Heat shrink insulates the exposed wires and to reduce it to the correct size you can use either a soldering iron or a heat gun
6. Before and after testing, it is recommended to check the filter and ensure that it is still in proper condition. The filter is rated to run for 6 months on moderate daily usage. However, this number can vary greatly depending on the amount of usage and the type of particles that are filtered. It is recommended to keep a detailed record of how often the filter is used, and what it is used for

4.5) Troubleshooting

If a test does not run successfully or you would simply like to inspect the device before operation, there are several components to check including the electronics, code, and tubing. Before beginning the technical troubleshooting procedure below, it is recommended to eliminate simple causes for error such as the power cord not being plugged in or a loose tubing connection.

1. In the event that a test does not start when expected, first ensure that the Arduino program has been uploaded and that the Arduino is receiving power
2. Whenever the USB cord is plugged into the computer and connected to the Arduino, power will be delivered to the system and a green light will illuminate on the Arduino board
3. Then check that the “POWER” and “RUN TEST” switch are on. This should be confirmed by corresponding green LEDs that will illuminate when these switches are flipped
4. Also check that the 12V wall power adapter is plugged in
5. Next open the control box and check for any damaged, exposed or unplugged wires
6. First check that the connections between the Arduino and the relay board are correct. Refer to Figures 9 and 10 for the correct wiring
7. Then confirm that the “POWER” and “RUN TEST” switches are wired according to Figure 11A and 11B
8. Next, look at the connections between the solenoid valves and the relay board as shown in Figure 12. Power should be connected to one side of the solenoid while the other is connected to the normally closed port on the relay. This ensures that when there is not a signal sent to the relay, all solenoids should be closed. A relay, shown in Figure 12 includes three ports: normally open (NO), communication (COM), and normally closed (NC). The COM switch should always be connected to ground.

5.) Appendices

5.1) Appendix A: Video Demonstration of System

System Overview: <https://www.youtube.com/watch?v=JjYWKVQtMkY>

System Operation: <https://www.youtube.com/watch?v=vrY7NL2wlms>

QR Code for Scanning:



