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Materials and assembly for a portable soil greenhouse gas flux collection case

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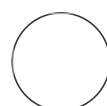
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ABSTRACT

The collection of soil nitrous oxide, carbon dioxide, and methane greenhouse gas (GHG) flux measurements utilizing static chamber sampling methodology can be both time and labor intensive. The development of an automated field sampling system would allow for the collection of soil GHG samples from multiple static chamber sites more quickly and efficiently (Arnold et al., 2001). This document describes the material assembly of a modified version of the Chamber Automated Sampling Equipment (FluxCASE) from Davis et al., 2018. This automated GHG case is compatible with existing soil GHG static hoods and requires minimal field training to use. The automated GHG case main components are: one 12-volt marine battery, five solenoid valves with attached syringes, a microcontroller, and an actuator. Estimated materials costs for assembly and building one automated GHG case is approximately $600.00 (2024 dollars).

IMAGE ATTRIBUTION

Rachel E. Clarkson

GUIDELINES

- Manufacturing of 3-D printed parts are required for the actuator assembly.
- 3-D materials used may affect the durability of the purge syringe with the actuator.
- We recommend using pre-cut jump wires rather than spools of wire to save time.

MATERIALS

	A	B	C	D	E	F	G
	Item Name	Quantity required per case	Details	Quantity per order	Manufacturer	Potential Supplier	Part/Model #
	8 channel relay module	1		1	Progressive Automations	Progressive Automations	LC-202
	solenoid valve	5	1/8 NPT Direct Acting 3 Way Solenoid Valve (12VDC DIN), 200C coil	6	STC (Sizto Tech Corp)	STC (Sizto Tech Corp)	3V1-1/8-1-D
	actuator	1	Input Voltage: 12VDC, Full Load: 35lbs, Type of Duty:25%, Stroke: 3, Degree of Protection. IP54	1	Firgelli Automations		FA-35-S-12-3 (5:1)
	Nylon Plastic Check Valve with Barbed Fittings (Check Valve with Barb)	1	Ball, 1/8 Inlet Tube ID x 1/8 NPT Male Outlet	1	McMaster-Carr	McMaster-Carr	6079T124
	Plastic Pipe Fitting for Oil, Plug with External Hex Drive Style, 10-32 UNF Male (Plug)	5	Plug with External Hex Drive Style, 10-32 UNF Male	1	McMaster-Carr	McMaster-Carr	8316T33

	A	B	C	D	E	F	G
	Compact Plastic Threaded Check Valve 1/8 NPT Male X 1/8 NPT Male (Check Valve)	1	1/8 NPT Male X 1/8 NPT Male	1	McMaster-Carr	McMaster-Carr	1424T11
	Medium-Pressure Aluminum Threaded Pipe Fitting (Straight Connector)	3	Straight Connector, 1/8 NPT Male	1	McMaster-Carr	McMaster-Carr	3861T81
	Plastic Quick-Turn Tube Coupling (External Quick-Turn Tube Coupling)	1	Plugs, for 1/8 Barbed Tube ID, Nylon	10	McMaster-Carr	McMaster-Carr	51525K123
	Plastic Barbed Tube Fitting for Air and Water (Barbed Elbow)	1	Tight-Seal, Elbow, 1/8 ID x 1/8 NPT Male, White	10	McMaster-Carr	McMaster-Carr	5463K485
	Plastic Quick-Turn Tube Coupling (Luer Lock Socket)	4	Sockets, 1/8 NPT Male, White Nylon Plastic	10	McMaster-Carr	McMaster-Carr	51525K439
	Plastic Quick-Turn Tube Coupling (Quick-Turn Tube Coupling)	1	Sockets, for 1/8 Barbed Tube ID, Polycarbonate	10	McMaster-Carr	McMaster-Carr	51525K283
	Rustrictor Field Box Large	1	Rustrictor Field Box Large- 1612; UPC: 00024099009867	4	Plano	Caprice Electronics	PLA1612R
	30 mL Syringes	4	Bulk Syringes, Nonsterile	225	Avantor	BD Medical	BD 301033
	50 mL Syringe	1	50 mL Syringe Disposable Luer Lok Sterile	40	Midland Scientific	Midland Scientific	BD 309653

	A	B	C	D	E	F	G
	14 Red Stranded CU THHN Wire (Red Stranded #14 Wire)	5 feet (approx.)	Wiring for outlets, switches and other loads; copper; 14 amps max	50 feet	Southwire	Home Depot	22957583
	18 Black Solid CU TFN Fixture Wire (Black Solid #18 Wire)	2 feet (approx.)	#18 AWG wiring; rated 600V	500 feet	Southwire	Home Depot	26977906
	Tygon S3 Lab Tubing (Plastic Tubing)	approx. 1.5 feet	E-3603 1/8 x 1/4	100 feet	Saint-Gobain	Midland Labs	SAINT GOBAIN ACF02007
	Machine Screw: M3 Thread Size, 35 mm Lg, Steel, Zinc Plated, Pan, Phillips, Metric (Machine Screw)	5		100	Grainger	Grainger	6GE50
	Hex Nut: M3-0.50 Thread, 5.5 mm Hex Wd, 2.4 mm Hex Ht, Steel, Class 6, Zinc Plated (Hex Nut)	5		100	Grainger	Grainger	6CA69

	A	B	C	D	E	F	G
	20cm Length Jumper Wire/Dupont Cable Multicolored (10 Color) M to F, M to M, F to F Each 40pin for Prototype Breadboard/DIY/Raspberry Pi 3, 4/Orange pi/BBC Micro: bit/Makeymakey (Jump Wires)	11		120	Haitronic	Amazon	X00187CA4J
	DC Converter Step Down (5V 3A 15W) (Converter Box)	1		1	Tobsum Binzet	Amazon	X002EJ5Q5F
	Sealed Rechargeable Battery	1	DC Power: Constant Voltage Charge, Cycle Use: 14.4-15V, Standby Use: 13.5-13.8V, Initial Current: 1.5A Max	1	Power Sonic (PS)	Amazon	PS-1250 F1. 12 Volt
	Terminal Strips 8p 15a (Terminal)	2		6	MilaPeak	Amazon	X001RH1R67 Or TB1508
	Rocker Switch	1	Rated Voltage: 12V DC, Mounting Size:20mm, Rate Current:20A, Wire Length: 200mm	4	Apiele	Amazon	KCD1-8-101NW Green Or X002U187DP
	Arduino Uno Rev.3	1		1	Arduino	Amazon	A000066

	A	B	C	D	E	F	G
	Plug Jack to Bare Wire Open End Pigtail (a/c Adaptor)	1	L-Shape replacement 5.5mm x 2.1mm DC power supply repair cable, 90-degree right angle plug to bare wire open end pigtail power cord.	4	Fancasee	Amazon	
	ReadyWired USB Cord Cable for Arduino UNO R3 Mega2560 Mega328 Nano (USB Type A)	1	USB Type A	1	ReadyWired	Amazon	
	Spade Wire Connector Electrical Crimp Terminal (Spade Connector)	2	Female Quick Disconnect; Insulated; 16-14 AWG 6.3mm FDD 2-250 Blue	100	Baomain Electric Inc.	Amazon	FDD 2-250
	Black Electrical Tape	1	3/4 (W) x 66' (L); Strong Self-Adhesive Waterproof Vinyl Tape	1	GTSE	Amazon	GTSE-ULPVC2019BLA-SL
	Teflon Tape	as needed	1/2 (W) x 520 (L) per 1 roll; PTFE material	4 rolls	Votmell	Amazon	VTM-V004
	Velcro	approx. 1 foot	Velcro Brand Heavy Duty Tape; 16' (L) x 1 1/2 (W);	16'	Velcro USA	Amazon	VEL-30838-USA
	Velcro Brand One-Wrap Cable Ties	1	8x1/2 Black Cord Organization Straps, Thin Pre-Cut Design,	100	Velcro USA	Amazon	91140
	4 Zip Ties	6	Zip Ties 4-inch, Small Zip Ties with 18lb Tensile Strength	200	Tantti	Amazon	

A	B	C	D	E	F	G
Male to male jump wire	5	Red 18 AWG Jumper Lead Pin to Pin Tin 8.86 (225.00mm)	10	Molex	Digikey	2147622123

Material list for flux case assembly

SAFETY WARNINGS

> ⓘ Do not attach the battery until you are certain everything is correctly wired, and you are done working with exposed wiring. Attaching the battery with incorrect wiring may short circuit the Arduino Board, rendering it useless. Additionally, attaching the battery to the circuit renders everything as "live" meaning any exposed wiring could result in an electrical shock.
>
> It is recommended that no changes are made to the provided code for the Arduino unless completely confident and familiar with coding. Changes to the provided code may cause the automated GHG case to function incorrectly.

BEFORE START INSTRUCTIONS

It is recommended to read both the protocol and watch the videos prior to assembly.

Plumbing the Flux Case

1   **Flip orientation of solenoid valves**

1.1   Remove the top screw from the solenoid valve using a medium Philips screwdriver, then carefully unplug the top wired portion making sure to keep the internal wiring tucked inside.

1.2   Once apart from the base, remove the screw and carefully using a small screwdriver push the internal wiring slightly out of the valve top.

1.3   Check the internal wiring to make sure it is well connected and tighten the internal screw.

1.4   Rotate the top of the valve 180° and reinsert.

1.5   Rotation of the top valve will allow for the head to be reinstalled onto the valve in the opposite direction. Reinsert the screw and tighten with medium Philips screwdriver.

2   **Insert and tighten the plastic plug in all five of the solenoid valves**

2.1   Cut the Teflon tape in half lengthwise to create two thin strips.

2.2   Wrap the Teflon tape around the plug twice in the opposite direction than it turns into the valve (counterclockwise).

2.3   Carefully thread the plug into the hole on the valve, making sure it is inserted straight.

2.4   Use a ¼ inch wrench to carefully tighten the plug, making sure it is tight, but without stripping the threads on the plug.

2.5   Complete this on all five solenoid valves

3   **Tighten the bolt with the plastic plugs inserted into them using an adjustable wrench until tight.**

4   **Connect the Purge and First Solenoid Valve.**

4.1   First insert both long screws into the holes on the purge solenoid valve (Figure 1).
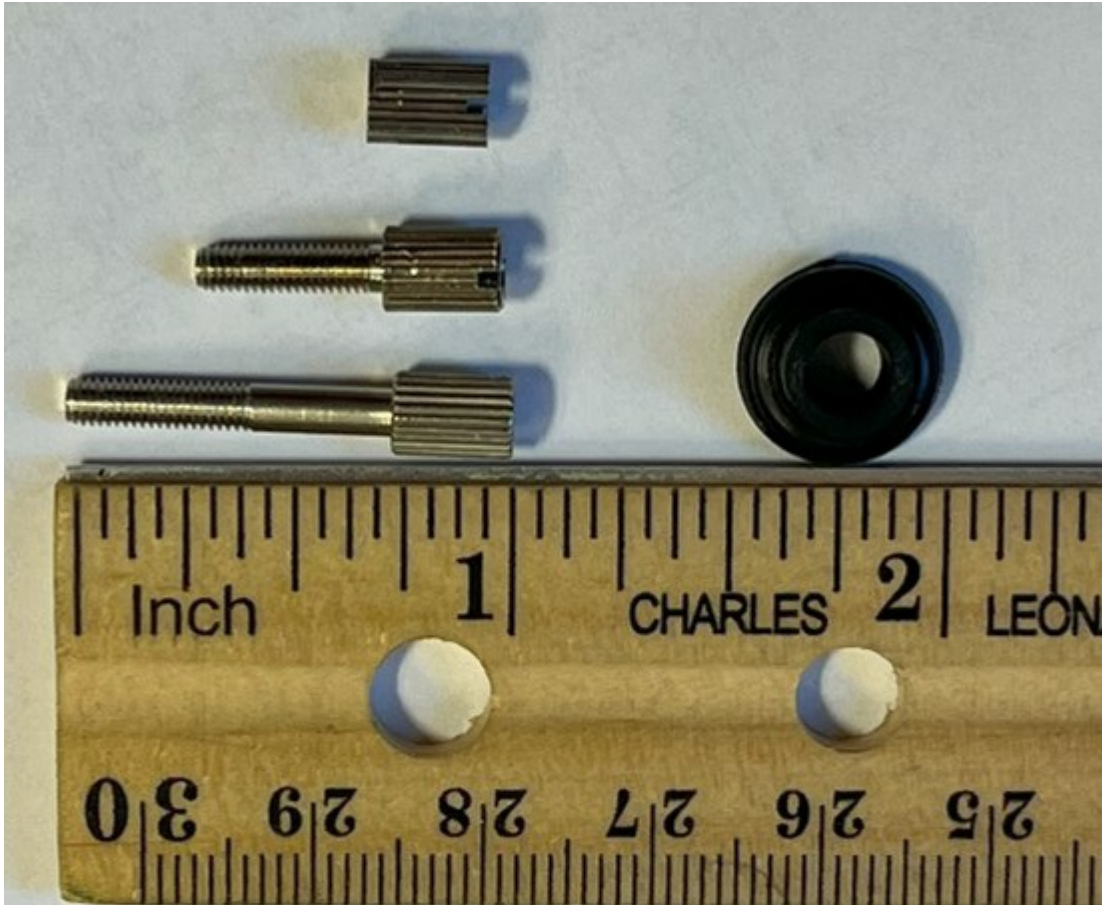
Figure 1. Part sizing for solenoid valve connection (Nut-top left; short screw-middle left; long screw-bottom left; o-ring-bottom right) Nut, screws, and o-ring are included with solenoid valve.

4.2   Flip the valve over and screw the back ends of the short screws onto the long screws (Figure 1).

4.3   Place the rubber o-ring in the larger opening of the solenoid valve (Figure 2) and then carefully place the first solenoid valve over the purge making sure to guide the screws through the holes on the first.
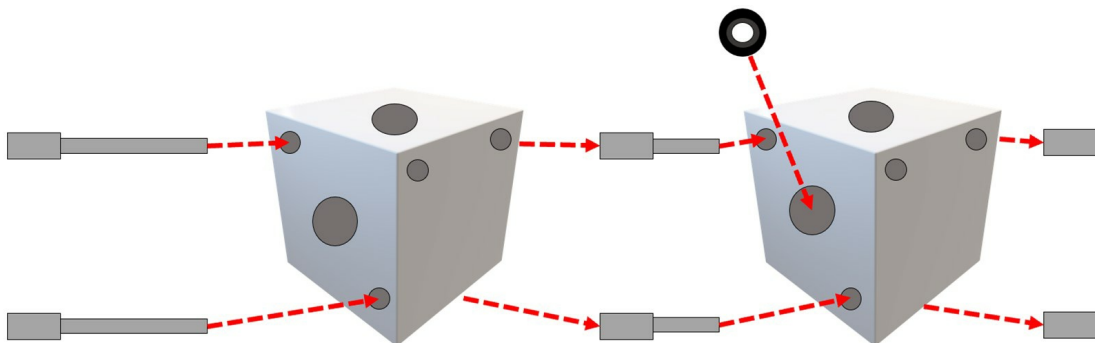

Figure 2. Connection of purge solenoid valve to the first solenoid valve

4.4   Screw the two nuts onto the ends of the short screws through the first solenoid valve.

4.5   Tighten the screws together using 2 medium size flat head screwdrivers until the two solenoid valves are fitted tightly together.

5   **Connect the solenoid valves together using the aluminum threaded straight connectors.**

5.1   Wrap the threads twice around using Teflon tape going the opposite direction of which the straight connector threads in.

5.2   Thread the straight connector into the right side of the first solenoid valve and tighten using a 6″ crescent (adjustable) wrench.

5.3   Wrap the threads twice on the other end of the straight connector with Teflon tape going the opposite direction of which the straight connector threads in.

5.4   Thread the straight connector into the left side of the second solenoid valve and tighten it down, making sure the first and second solenoid valves are as straight as possible with each other.

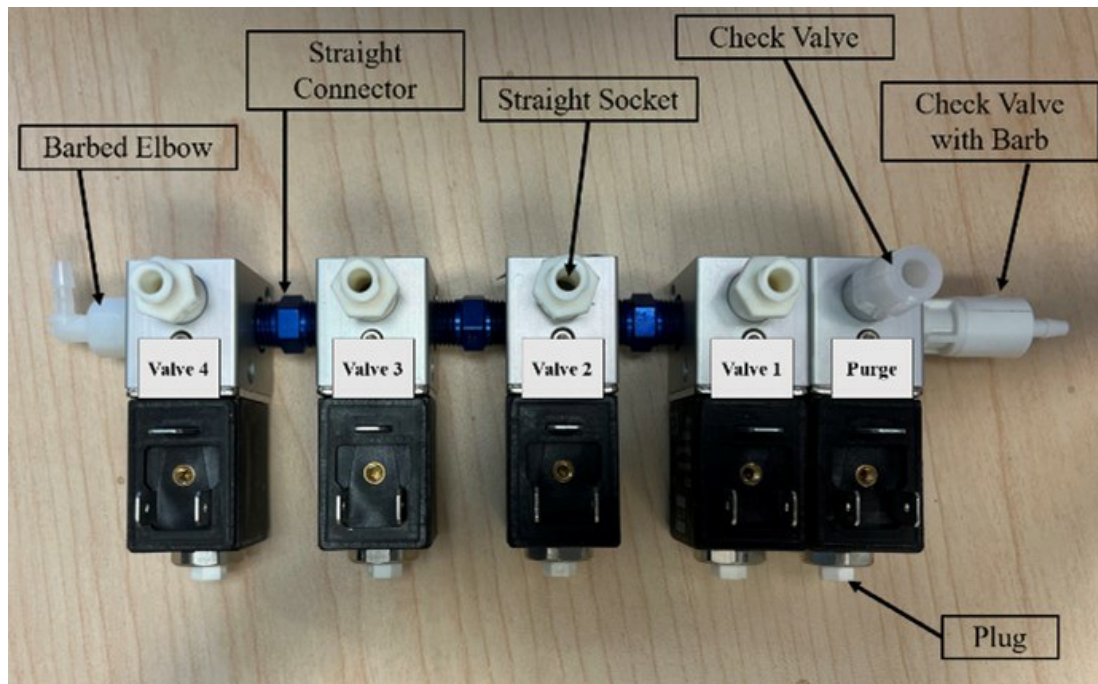**5.5**   Repeat with the other two straight connectors (Figure 3).

Figure 3. Solenoid valve plumbing assembly diagram.

6   Connect the Nylon Check Valve to the top of purge valve (Figure 3).

6.1   Wrap the threads twice around using Teflon tape going in the opposite direction of which the check valve threads into.

6.2   Carefully thread the solid portion of the nylon check valve into the top tapped hole of the purge valve, making sure to thread straight into the purge valve.

6.3   Once the check valve is threaded into the top of the purge valve, tighten the check valve using a 6 inch crescent wrench taking caution to not over tighten and strip the plastic threads.

7   Connect the Luer-Lock straight sockets to the top of valves 1-4 (Figure 3).

7.1   Wrap the threads twice around using Teflon tape going in the opposite direction which the Luer-lock socket threads in.

7.2   Carefully thread the Luer-lock socket into the top hole of Valve 1 (Figure 3), making sure it is threaded in straight.

7.3   Once the Luer-lock socket is threaded in, tighten it using a 6 inch crescent wrench, taking caution to not over tighten and strip the threads.

**7.4**   Repeat steps 7.1 to 7.3 for valves 2 through 4.

8   **Connect the check valve with hose barb to the side of the purge solenoid valve (Figure 3).**

8.1   Wrap the threads twice around using Teflon tape (going in the opposite direction of which the check valve with barb threads into).

8.2   Carefully thread the check valve with hose barb into the purge valve tapped hole.

8.3   Once the check valve with hose barb is threaded in, tighten it using a 6 inch crescent wrench taking caution to not over tighten and strip the plastic threads.

9   **Connect the barbed elbow to the side of solenoid valve 4 (Figure 3).**

9.1 Wrap the threads twice around using Teflon tape going in the opposite direction of which the barbed elbow threads into.

9.2 Carefully thread the barbed elbow into the tapped hole, making sure it goes in straight.

9.3 Once the barbed elbow is threaded in, tighten it using a 6" crescent wrench taking caution to not over tighten and strip the threads. When finished tightening, barbed elbow should be facing towards the back of the solenoid valves (away from from the Luer-Lock straight socket).

10 **Video instruction for plumbing the flux case.**
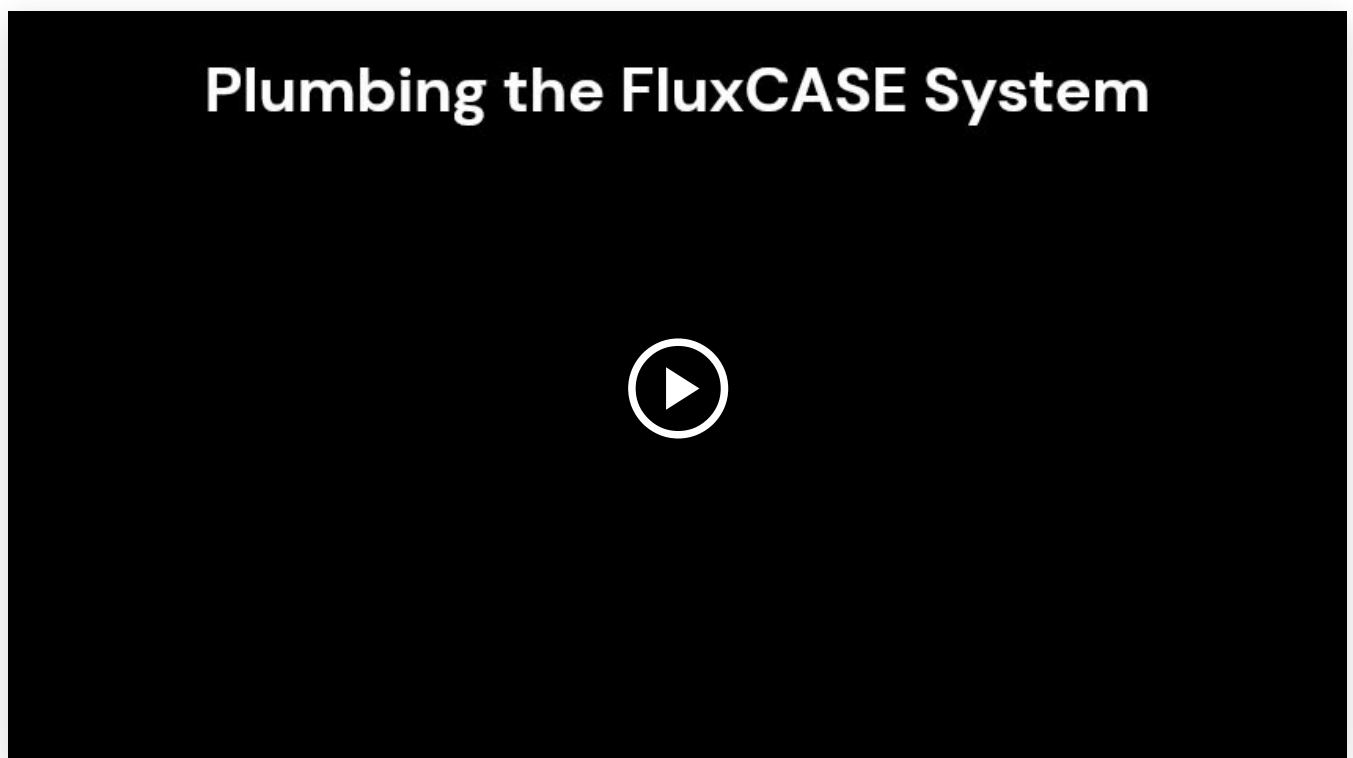
Wiring the Flux Case

11 **Wiring Steps**

> **Note**
>
> **Tools required:**
> wire cutter
> wire strippers
> precision screwdrivers
> medium Philips screwdriver
>
> **Materials:**
> Assembled solenoid valve system
> (1) 8-relay module
> (1) actuator
> red stranded #14 wire (58.5 inches)
> black solid #18 wire (16 inches)
> (1) convertor box
> (11) jump wires
> (1) red terminal barrier strip
> (1) black terminal barrier strip
> (1) 12V battery
> (1) rocker switch
> (2) jump wires with spade connectors
> (1) Arduino
> (1) a/c adaptor
> (2) spade connectors
> (2) 4 inch zip ties
> electrical tape

11.1 Cut the following wires to the designated length:
- 8-2 inch long black wire (solid copper #18)
- 4-8 inch long red wire (stranded #14 ANG)
- 1-8.5 inch long red wire (stranded #14 ANG)
- 1-7 inch long red wire (stranded #14 ANG)
- 1-11.5 inch long red wire (stranded #14 ANG)

11.2 Use the wire strippers to strip approximately 1/8" to 1/4" of the outer wire insulator, exposing the inner wire. Complete this on both sides of all the wires cut in step 11.1.

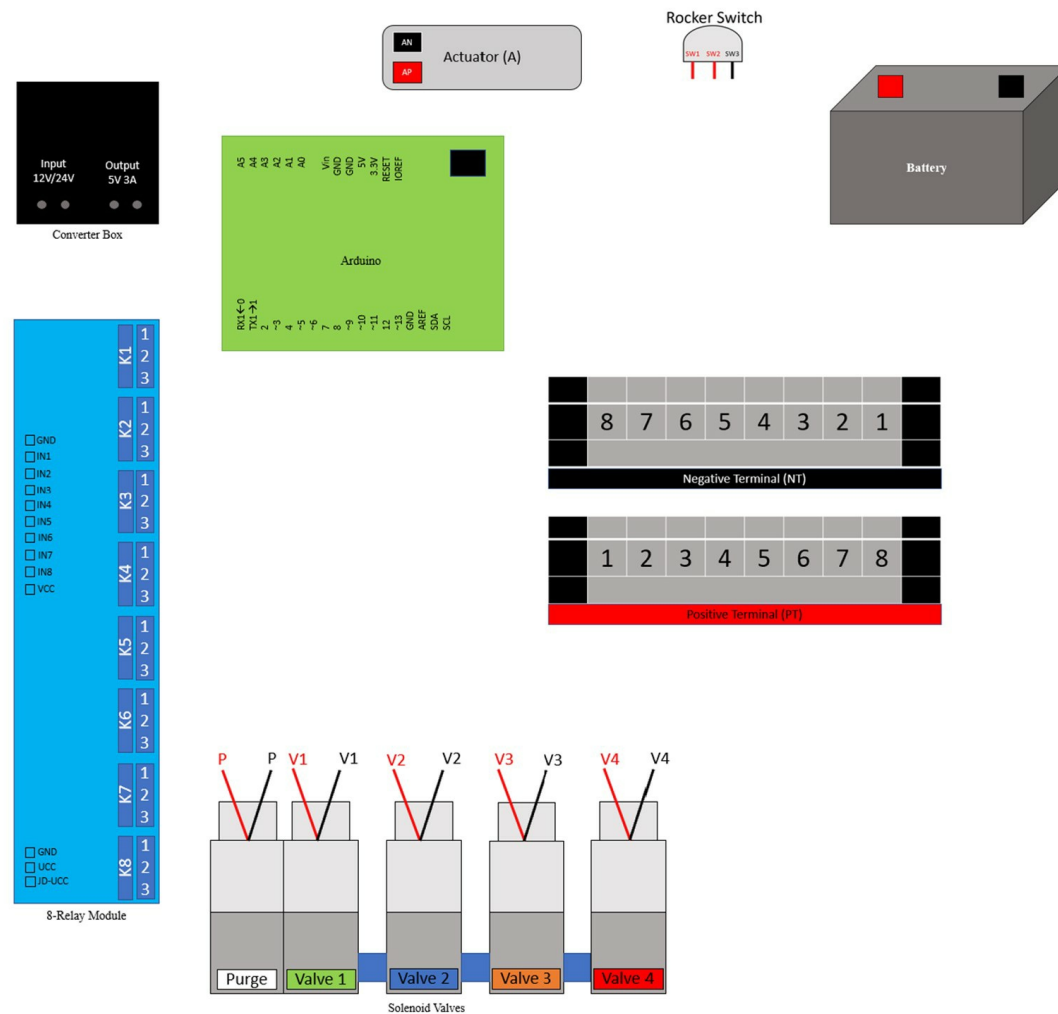**11.3** Arrange the electrical components following Figure 4.

Figure 4. Electrical component arrangement.

11.4   Connect the terminals with the terminal barrier strips.
1. Remove the plastic cover on the terminals, then use a medium Philips screwdriver to loosen the screws on one side of the strip.
2. On one terminal insert a red (positive) terminal barrier strip, then tighten the screws using a medium Philips screwdriver.
3. Complete this with the other terminal strip, but instead with the black (negative) terminal barrier strip.

11.5   Wire the valves, positive (red) to positive terminal (red-PT) following the connections chart below.

A	B	C
Positive valve wires (red)		Positive terminal (red)
Purge	>>>>	PT2
Valve 1	>>>>	PT3
Valve 2	>>>>	PT3

A	B	C
Valve 3	>>>>	PT4
Valve 4	>>>>	PT4

Once the wires are in place, tighten down the screws in the positive terminal using a medium Phillips screwdriver. Make sure the wired connections are secure.

11.6   Wire the valves, negative (black) to the relay module (Figure 5) following the connections chart below.

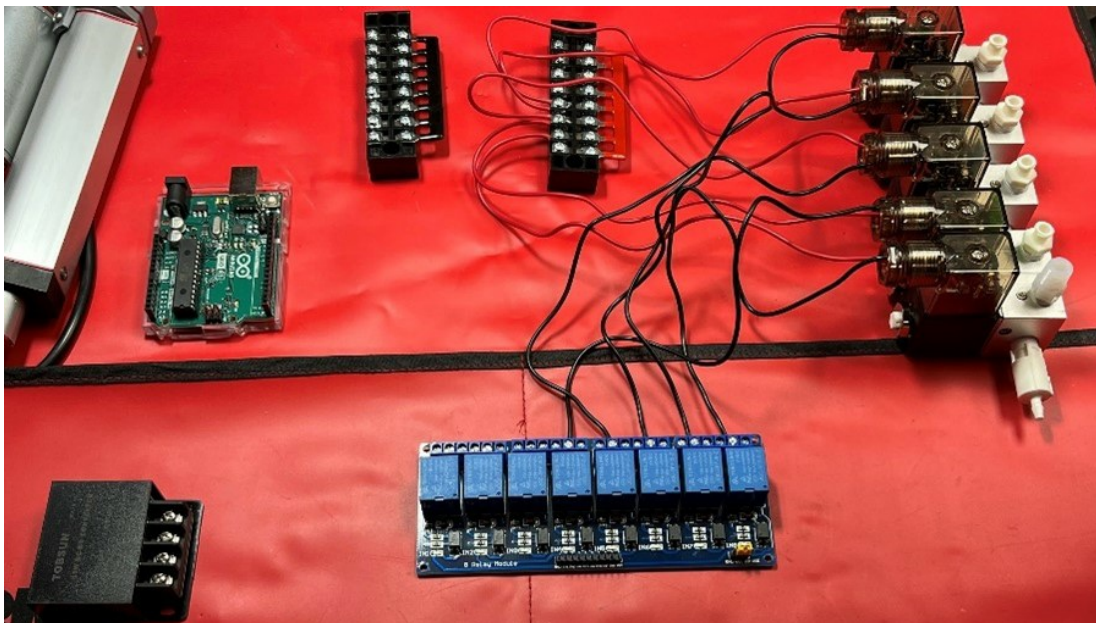| A	B	C
Negative valves wire (black)		Relay module
Purge	>>>>	K8:2
Valve 1	>>>>	K4:2
Valve 2	>>>>	K5:2
Valve 3	>>>>	K6:2
Valve 4	>>>>	K7:2

Figure 5. Solenoid valve wiring

11.7   Wire the actuator to the relay module following the connections chart below.

A	B	C
Actuator		Relay module
Positive (red)	>>>>	K1:2

A	B	C
Negative (black)	>>>>	K2:2

11.8   Finish wiring the relay module (Figure 6) following the connections chart below:

A	B	C
Relay module		Negative terminal
K1:1	>>>>	NT7 (8" red wire)
Relay module		Positive terminal
K2:3	>>>>	PT7 (8" red wire)
Relay module		Relay module
K1:1	>>>>	K2:1 (2" black wire)
K2:1	>>>>	K3:3 (2" black wire)
K3:3	>>>>	K4:3 (2" black wire)
K4:3	>>>>	K5:3 (2" black wire)
K5:3	>>>>	K6:3 (2" black wire)
K6:3	>>>>	K7:3 (2" black wire)
K7:3	>>>>	K8:3 (2" black wire)
K1:3	>>>>	K2:3 (2" black wire)

Figure 6. Relay module wiring

Once all the wires are in place use a precision screwdriver with a Philips head to tighten down all the screws in the relay module. **Make sure the wired connections are tight and secure.** Additionally, use a medium Philips screwdriver to tighten the screws in NT7 and PT7.

11.9   Wire the converter box following the connections chart below.

A	B	C
Converter box		Connection
12V	>>>>	PT5 (8" red wire)
24V	>>>>	NT6 (8" red wire)
5V	>>>>	GND (module) jump wire
3A	>>>>	JD-UCC (module) jump wire

> **Note**
>
> Before beginning to wire the last two jump wires on the relay module, remove the cap (yellow) from the relay module.

Once all the wires are in place, use a medium Philips screwdriver to tighten down all the screws.

Make sure the connections are secure.

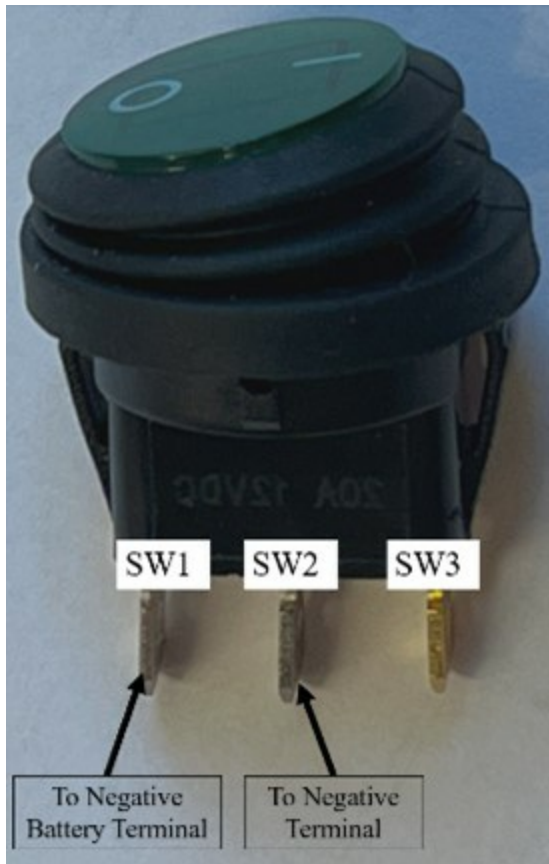11.10   Connect the spades on the pre-soldered wires to the SW1 and SW2 positions on the rocker switch (Figure 7).

 Figure 7. Rocker switch connections

Wire the rocker switch following the connection chart below.

A	B	C	D
Rocker switch		Terminal	Wiring
SW1	>>>>	Negative battery	Blue connection with spliced red stranded wire (7 inches)
SW2	>>>>	NT1	Black connection with spliced red stranded wire (11.5 inches)
SW3 (gold connection)		No connection	

Securely connect a spade wire connector to the end of the red stranded wire so it can be connected to the negative battery terminal.

11.11   Wire the A/C Connector following the connections table below.

A	B	C
A/C connector		Terminal

A	B	C
Positive (red)	>>>>	PT1
Negative (black)	>>>>	NT8

The A/C connector should be negative on the outside and positive on the inside.

11.12   Wire the connections for the positive battery terminal following the connections table below.

A	B	C
Battery terminal		Positive terminal
Positive	>>>>	PT8 (8.5" red wire)

Securely connect a spade wire connector to the end of the red wire for connections to the positive battery terminal.

12   Wire the Arduino to the relay module.

⚠️

12.1   Wire the Arduino to the relay module using jump wires by following the connections table below.

A	B	C
Arduino		Relay module
8	>>>>	IN1
9	>>>>	IN2
2	>>>>	IN3
3	>>>>	IN4
4	>>>>	IN5
5	>>>>	IN6
6	>>>>	IN7
7	>>>>	IN8
5V	>>>>	UCC

> **Note**
>
> Make sure all connections are in the correct order listed.

12.2   Use two small zip ties to connect the plastic base of the Arduino to the Arduino board.
1. Thread the zip ties through the base and tighten so that the head of the zip tie is located on the top of the Arduino.
2. Once tight, cut off the excess zip tie ends.

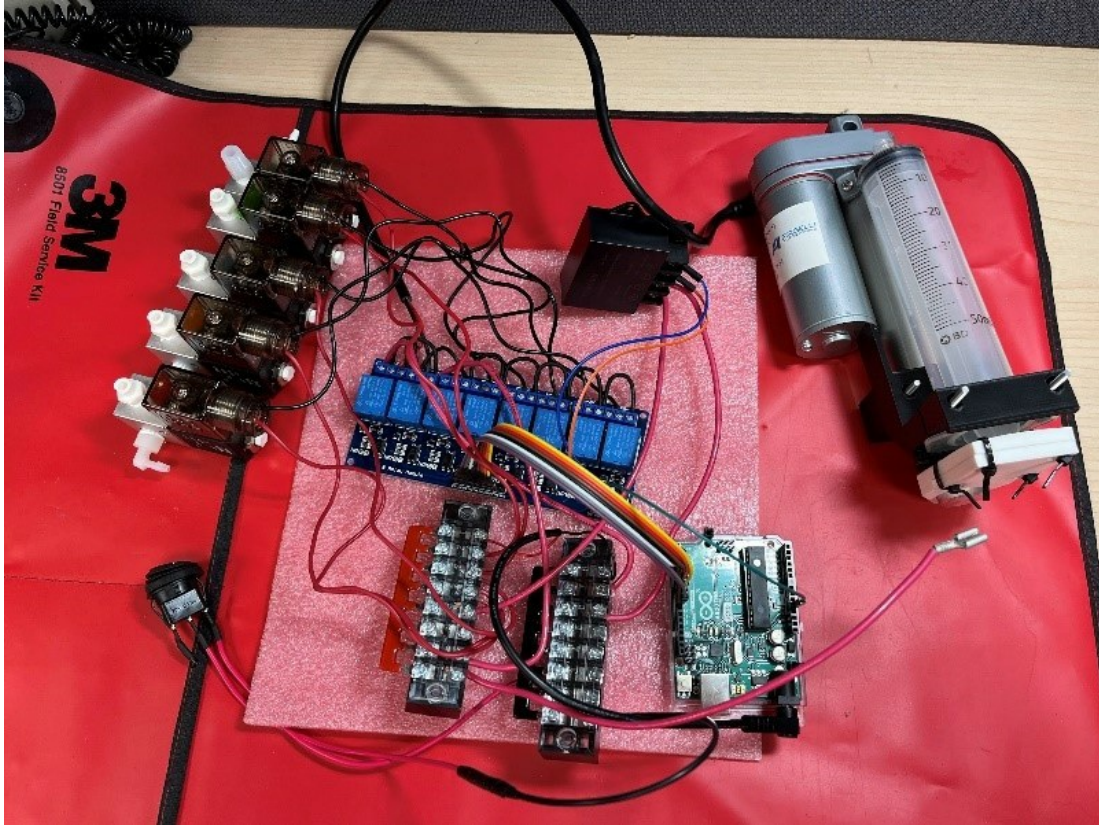**12.3**   Plug the A/C connector into the Arduino (Figure 8)

Figure 8. Completed wiring of the flux case.

12.4   Connect to the 12V battery
- Once all the connections and double checked and correct connect the positive connection to the positive end of the battery and the negative connection to the negative end of the battery.

13   **Video instruction for wiring the flux case.**

Wiring the FluxCASE

Connecting the Purge Syringe to the Actuator

14   **Purge syringe (50 mL) and actuator assembly**

> **Note**
>
> **Tools required:**
> precision screwdriver
> small file
> needle nose pliers
>
> **Materials required:**
> (5) machine screws
> (5) hex nuts
> (1) 50 mL syringe
> (4) small zip ties
> (6) 3-D printed parts

14.1   Pull the plunger out of the 50mL syringe barrel and take off the rubber seal (Figure 9).

Figure 9. Syringe components.

14.2 Slide 3-D print part #3 (Figures 10, 11) onto the plunger with the ledge facing towards the plunger flange.
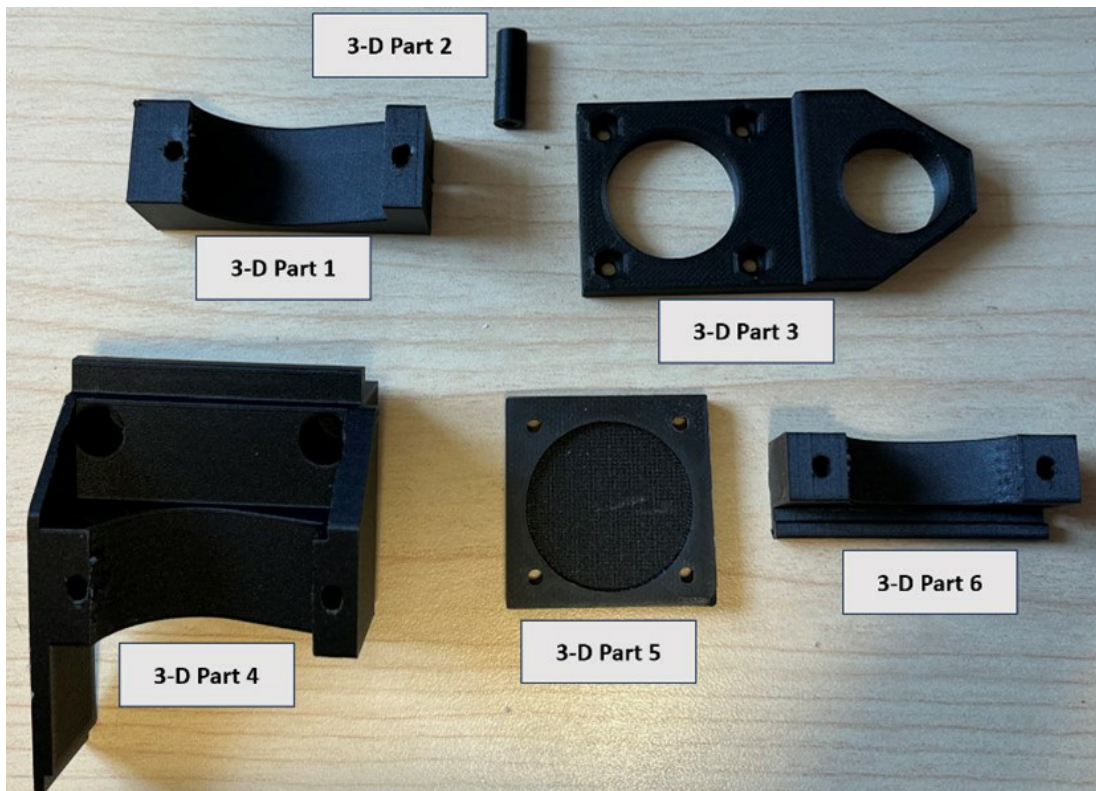

Figure 10. 3-D printed parts for the syringe installation on the actuator

14.3 Reattach the rubber seal on the plunger and press the plunger back into the barrel of the syringe.

14.4 Attach 3-D printed part #5 (Figure 10) onto the plunger flange (Figures 11, 12). Ensure the circular flange fits into part #5.
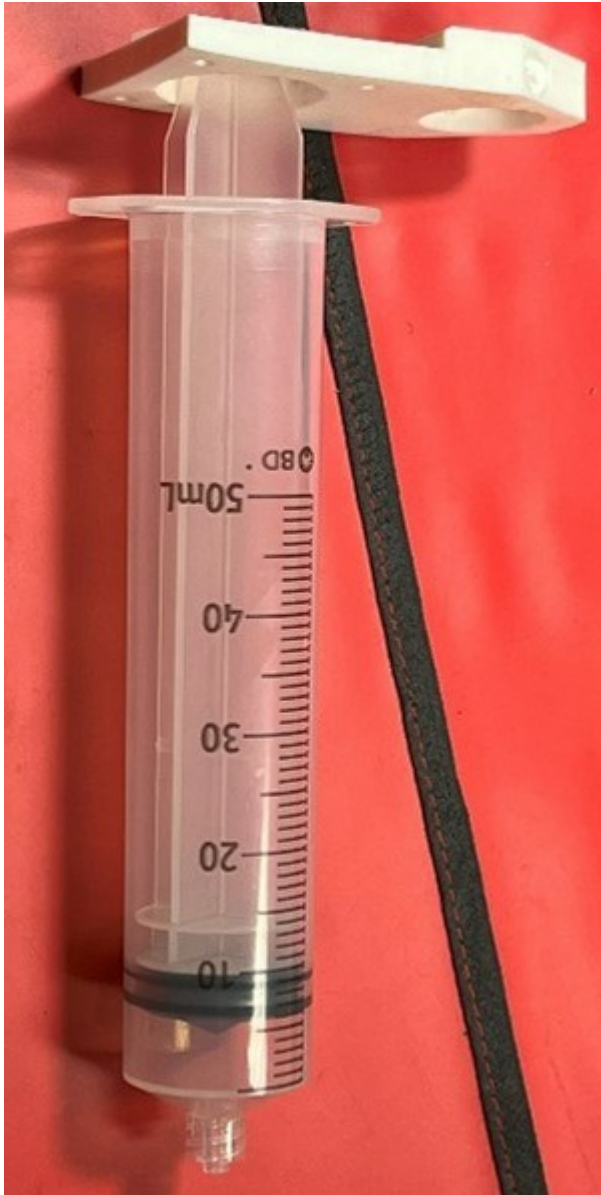
Figure 11. Syringe plunger with 3-D printed part 3 attached.

14.5 Use small zip ties to secure 3-D printed parts #3 and #5 together over the plunger flange. Insert the zip ties through part #3 out of part #5 and be sure to orient the zip ties in different directions so pieces are pulled together equally in all directions.

> **Note**
>
> Use needle nose pliers to pull the zip ties to ensure a tight fit between 3-D printed parts #3 and #5.

14.6 Attach 3-D printed part #4 and #6 around the syringe, making certain the syringe barrel numbers are facing toward 3-D part 6 (Figure 12). Use (2) M3 machine screws and (2) M3 hex nuts to secure 3-D printed parts #4 and #6 together.
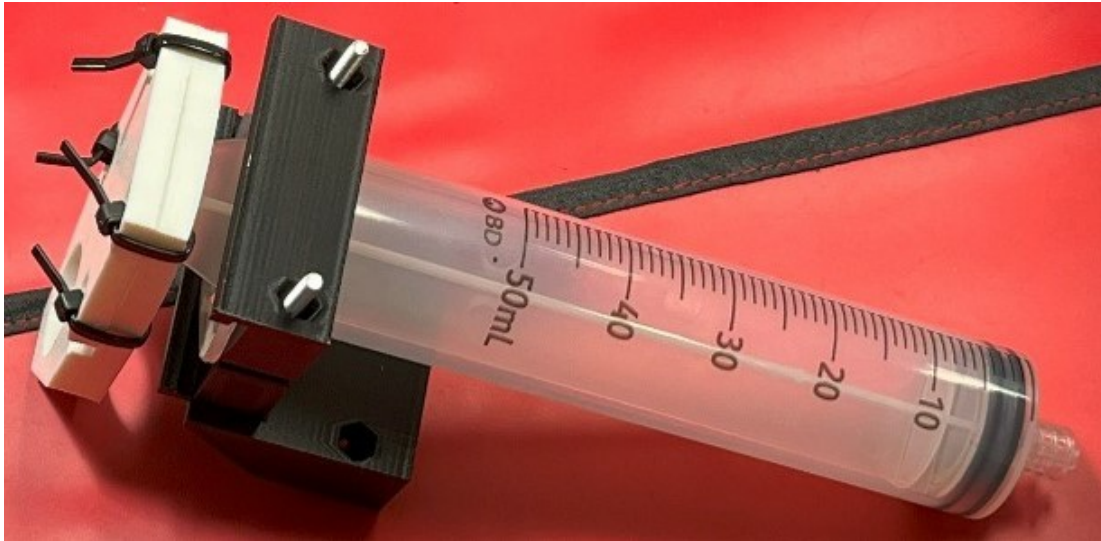
Figure 12. 3-D printed parts #4 and #6 attached to the syringe barrel.

> **Note**
>
> The M3 machine screws are inserted through Part #4 and attached to the M3 hex nuts through part #6. Use a precision (small) Philips screwdriver to tighten the machine screws until the 3-D printed parts #4 and #6 do not move on the syringe.

14.7   Insert 3-D printed part #2 through the hole at the top of the actuator.

14.8   Fit 3-D printed part #3 over the actuator facing the syringe so it lays over the actuator. Push part #3 down until the lines in the part line up with the holes on part #2.

> **Note**
>
> Using a small file, file the inside of part #2 as necessary.

14.9   Insert one M3 machine screw through the smooth hole and one M3 hex nut through the opposite end (hexagonal hole shape) and tighten with a precision Philips screwdriver.

14.10   Configure 3-D printed part #1 so it lines up with part #4 around the actuator.

14.11 Insert (2) M3 machine screws through the smooth holes and (2) M3 hex nuts on the opposite side and tighten using a precision Philips screwdriver (Figure 13).

Figure 13. Syringe mounted onto the actuator using 3-D part #1. Ensure there is a gap between 3-D printed parts #1 and #4 on the flat or square side of the actuator.

> **Note**
>
> DO NOT OVERTIGHTEN: The rounded portion ends of the 3-D printed parts #1 and #4 will end up touching, but the 3-D printed parts on the square or flat side of the actuator **should not touch**. Overtightening of the 3-D parts on the flat or square side will result in breaks in the 3-D printed material.

15 **Flip the rocker switch to test that the mounted parts and syringe are functioning properly prior to installation in the case.**

16 **Video instructions on connecting the purge syringe to the actuator.**

Syringe Installation on Actuator

Installation into the Case

17   **Installation case steps.**

> **Note**
>
> **Tools Required for this Section**
> Philips screwdriver (medium)
> Scissors
> 13/16 inch drill bit
> 1/4 inch drill bit
> Drill
> **Materials Required for this Section**
> Velcro (11.25 inches)
> plastic tubing (16.5 inches)
> external quick-turn coupling
> quick-turn coupling
> Velcro cable ties
> (4) 30 mL syringes

17.1   Drill a hole in the lid of the case on the side of the case with the hinges using the 13/16 inch drill bit (Figure 14) for rocker switch placement.

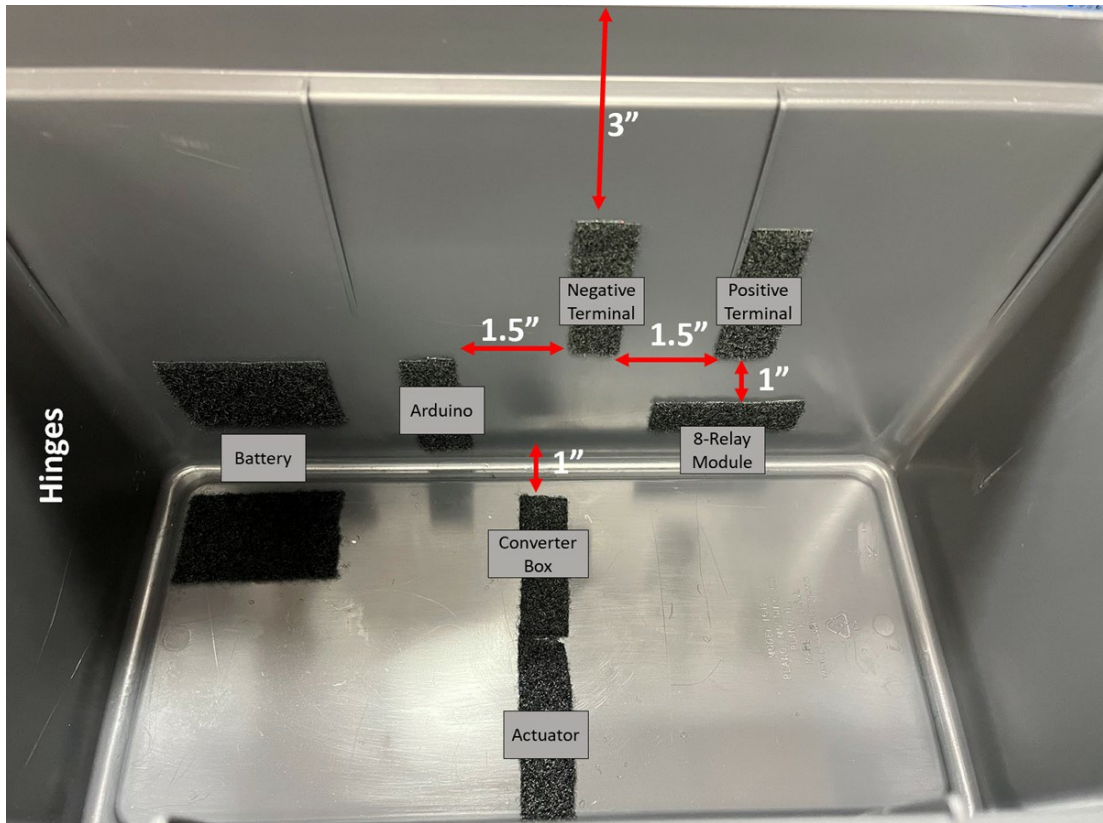Figure 14. Recommended 13/16 inch drill location for rocker switch.

17.2   Drill a hole on the side of the case using a 1/4 inch drill bit (Figure 15).

Figure 15. Recommended location to drill a 1/4 inch hole on the side of the case.

17.3   Disconnect the battery from the wiring circuit.

17.4   Disconnect the rocker switch electrical connection and insert into the 13/16 inch hole at the top of the case (Figure 14).

17.5   Cut Velcro to the following lengths:
- (6)-0.75 inch wide by 2.25 inch long pieces.
- (2)-1.5 inch wide by 2.25 inch long pieces.

17.6   Attach the Loop (Soft) Velcro to the inside of the case (Figure 16).

Hinges

3"

Negative Terminal

Positive Terminal

1.5"

1.5"

1"

Arduino

Battery

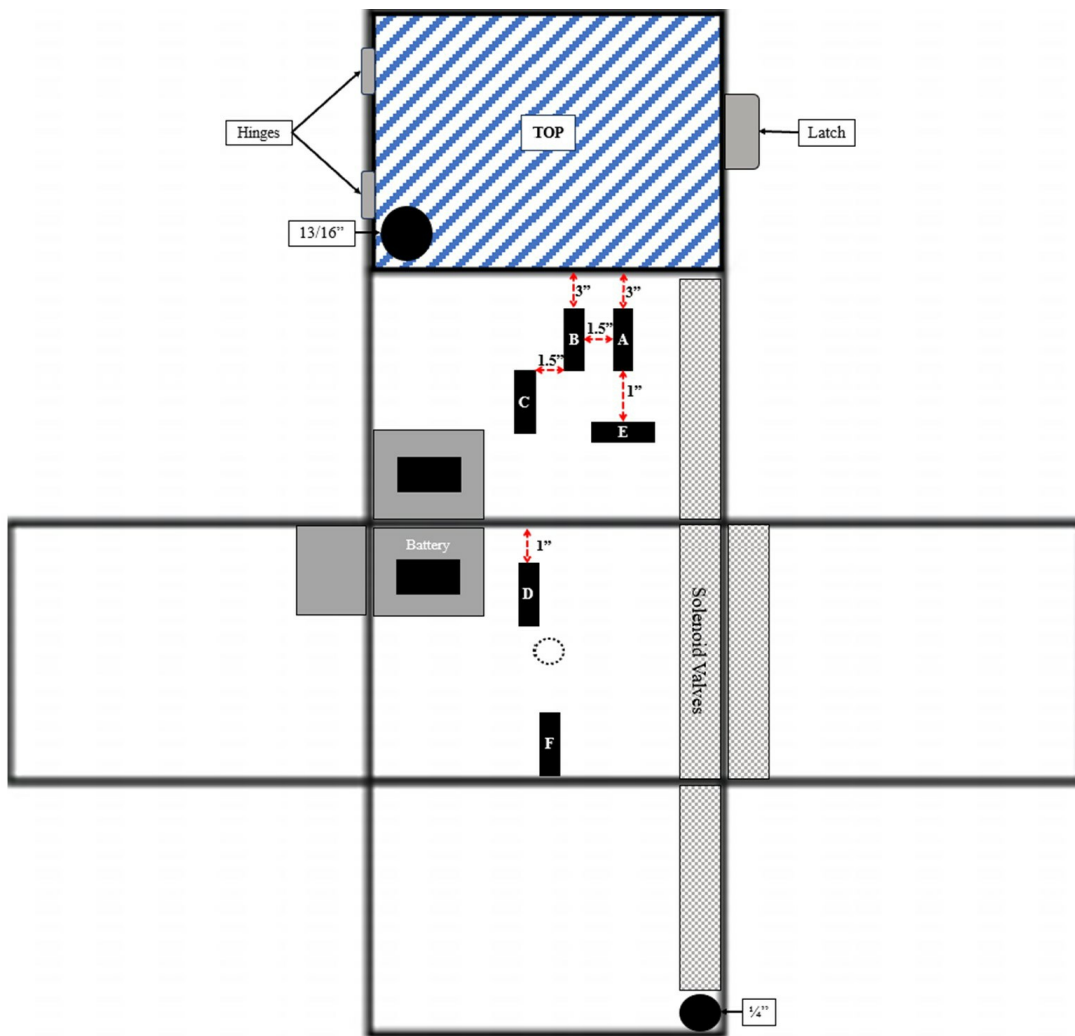8-Relay Module

1"

Converter Box

Actuator

Figure 16. Velcro (soft side) placement in the case.

17.7   Attach the Hook (Rough) Velcro to the back of each of the electronics as centered as possible.

> **Note**
>
> The Arduino, relay module, positive terminal, negative terminal, converter box, and actuator will require one 0.75 inch by 2.25 inch piece of Velcro per item.

17.8   The battery will be situated in the corner of the box below the 13/16" hole with the prongs facing into the middle of the case. It will have Velcro on one side of the battery and on the bottom (1.5 inch by 2.25 inch Velcro size). See Figure 16.

17.9   Cut plastic tubing to the following lengths.
- Inside case tubing-8 inches long
- Outside case tubing-8.5 inches long

17.10   Attach a Quick-Turn tube coupling to the end of the 8 inch long tubing and attach an external quick-turn tube coupling to the 8.5 inch long tubing.

17.11   Attach the end of the 8" tubing without the Quick-Turn coupling to the barbed elbow by pushing it onto the barb until the end of the tubing is flush with the back of the fitting.

17.12   From the outside of the case, insert the 8.5 inch piece of tubing without the Quick-Turn coupling through the 1/4 inch hole on the side of the case (Step 17.2).

17.13   Place the circuit assembly and solenoid valve assembly into the case and position it with the proper piece of Velcro it is meant to line up with (Figure 16). Additionally, make sure the solenoid valve assembly is positioned that the check valve with barb is aligned with the plastic tubing located in the 1/4 inch drill hole.

17.14   Push the check valve with barb into the plastic tubing (8.5 inch plastic tubing) so that it is flush with the back of the fitting. Align the check valve with barb so that it is located on the outside of the box through the 1/4 inch hole.

17.15   Lift the actuator syringe piece and screw on the Quick-Turn tube coupling connected to the 8 inch long tubing piece, then place the actuator back into place.

17.16   Reattach the rocker switch wires to the circuit, making sure to tighten down the screws as much as possible to hold the wires in place.

17.17   Use a Velcro cable tie to wrap around the last straight connector on the solenoid valves then through the hole on the outside of the case and back over the Velcro to secure it in place.

17.18   Place the battery into the case and attach the positive spade connector to the positive terminal of the battery and the negative spade connector to the negative terminal of the battery.

17.19 Attach the (4) 30-mL syringes onto the Luer-Lock socket connectors located on the solenoid valves.

> **Note**
>
> Overtightening the Luer-Lock socket connectors can cause thread stripping.

18 **Video instruction for installation into the case.**

Adding the Flux Case Software Program to the Arduino Board

19 **Program upload**

> **Note**
>
> **Tools required for this section**
> USB to USB Type A connection cable

19.1 Visit the Arduino website (https://www.arduino.cc/en/software) to download the Arduino software (2.1.0 or 2.1.1).

19.2 Connect the computer to the Arduino board using a USB Type A connection cable.

19.3   Pull up the Arduino software on the computer, click on the flux case program file, choose the program, and open it.

19.4   Once the flux case program is opened in the software, click the arrow button at the top left of the screen to transfer the program to the Arduino board.

19.5   Once the software program is successfully transferred, disconnect the USB Type A connection cable from the Arduino board.