Aquaponics System

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Purpose:

This system is a means to provide in-home, healthy, food production for people in urban environments where a garden could not typically be grown.

Function:

Firstly, this system will not discard any water.

Secondly, this system will not add any chemical fertilizer.

Thirdly, every item in this system will be fully used.

Initial Specifications:

- pH levels between 6.8 and 7.0
- 29 gallon tank
- LECA grow media
- 30 – 60 GPH
- 80 – 82 degrees Fahrenheit water temperature
- 16 hours of operation of the grow light

Design Calculations:

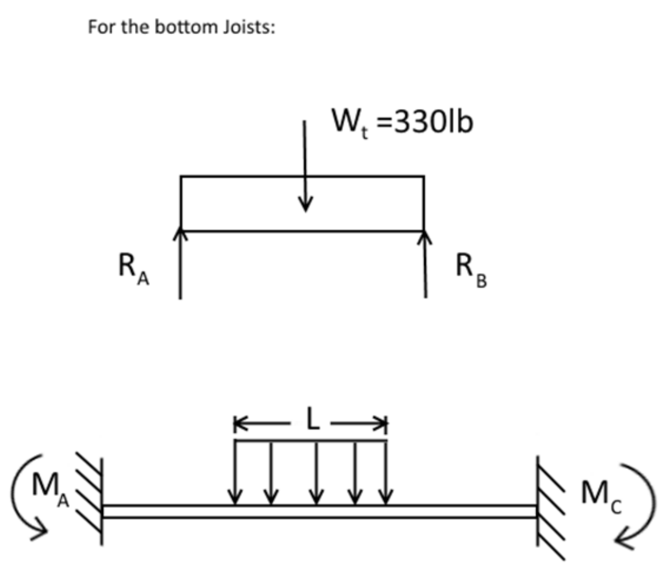


Figure 1 – Bottom Joist

Wt = Weight of fish tank + Weight of water = 330 lb

Reaction Force of A = Reaction Force of B = Wt / 2 = 330lb / 2 = 165lb

(The upper figure is Front View; Lower one is Right side view)

For the Right side view: $Ra + Rb = q * L$ $q = Ra / L = 165lb / 12.5in = 13.2lb/in$

$Mb = q*(L^2)/24 = 13.2lb/in*(12.5)^2/(24) = 86lb.in$

$Ma = Mc = -q*(L^2)/12 = 13.2lb/in*(12.5)^2/(12) = -172lb.in$

S>= Mmax / (allowable stress / factor safety); (factor safety number = 3, the material of joists is southern yellow pine, the allowable stress = 1400lb/in^2)

We have equation $S = b*h^2/6$ (Suppose b is equal to h)

$S >= 172lb.in / (467lb/in^2) = 0.4in^3$

$b*h^2 / 6 = 0.4in^3$

$b^3 = 2.4in^3$

$b = \sqrt[3]{2.4in^3}$

$b = 1.28in$

(The cross sectional area = 1.28in*1.28in =1.64in^2. We choose the cross sectional area of joist is 11.25in*1.5in = 16.875in^2 > 1.64in^2 therefore it is ok)

For the bottom brace:

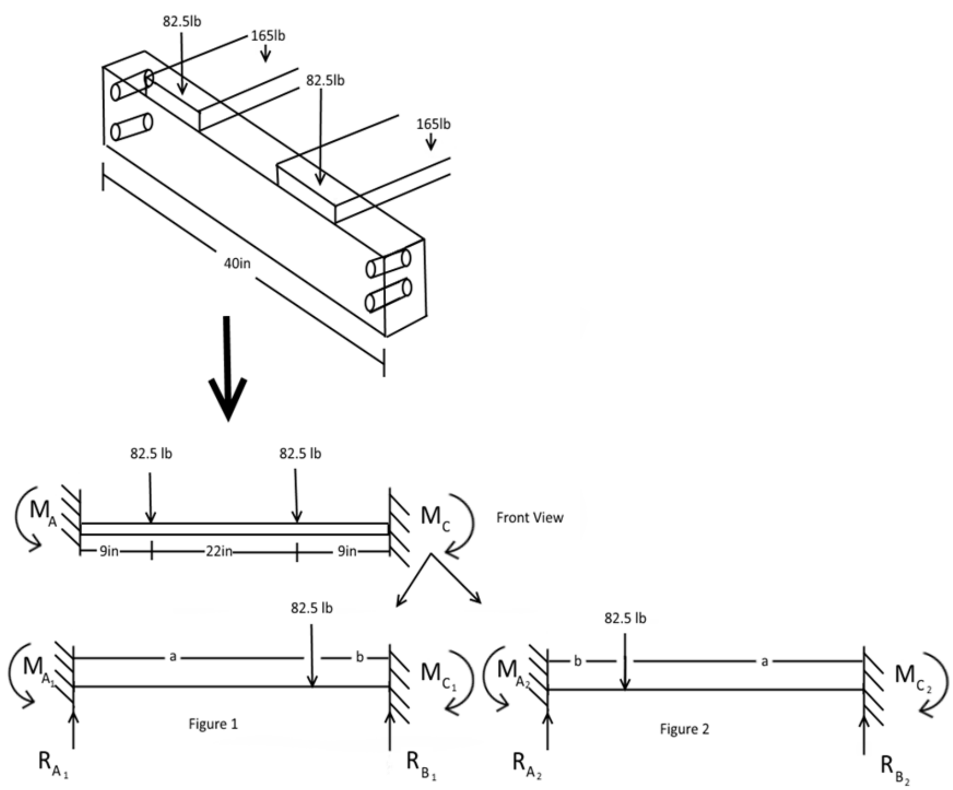


Figure 2 – Bottom brace.

Check the shear stress for each bolt:

Shear stress = P / A = 41.25lb / (π*(.015in/4)) = 3437.5lb/in^2

The material of bolt is steel, and the ultimate strength of the bolt we choose is 800MPa = 116030lb/in^2, so 116030lb/in^2 > 3437.5lb/in^2, the bolt is pretty strong.

Ma1 = (-P*a*b^2) / L^2 = (-82.5lb*31in*81in^2) / (40in)^2 = -129lb.in

Mb = (2*P*a^2*b^2) / (40in)^3 = 201lb.in

Mc1 = (-P*a^2*b) / L^2 = (-82.5lb*961in^2*9in) / (40in)^2 = -446lb.in

Ra1 = (P*b^2) / L^3*(3*a + b) = 11lb   Rc1 = (P*a^2) / L^3*(3*b + a) = 72lb

Ma2 = -446lb.in; Mb' = 201lb.in; Mc2 = -129lb.in; Ra2 = 72lb; Rc2 = 11lb

Figure 1 + Figure 2:

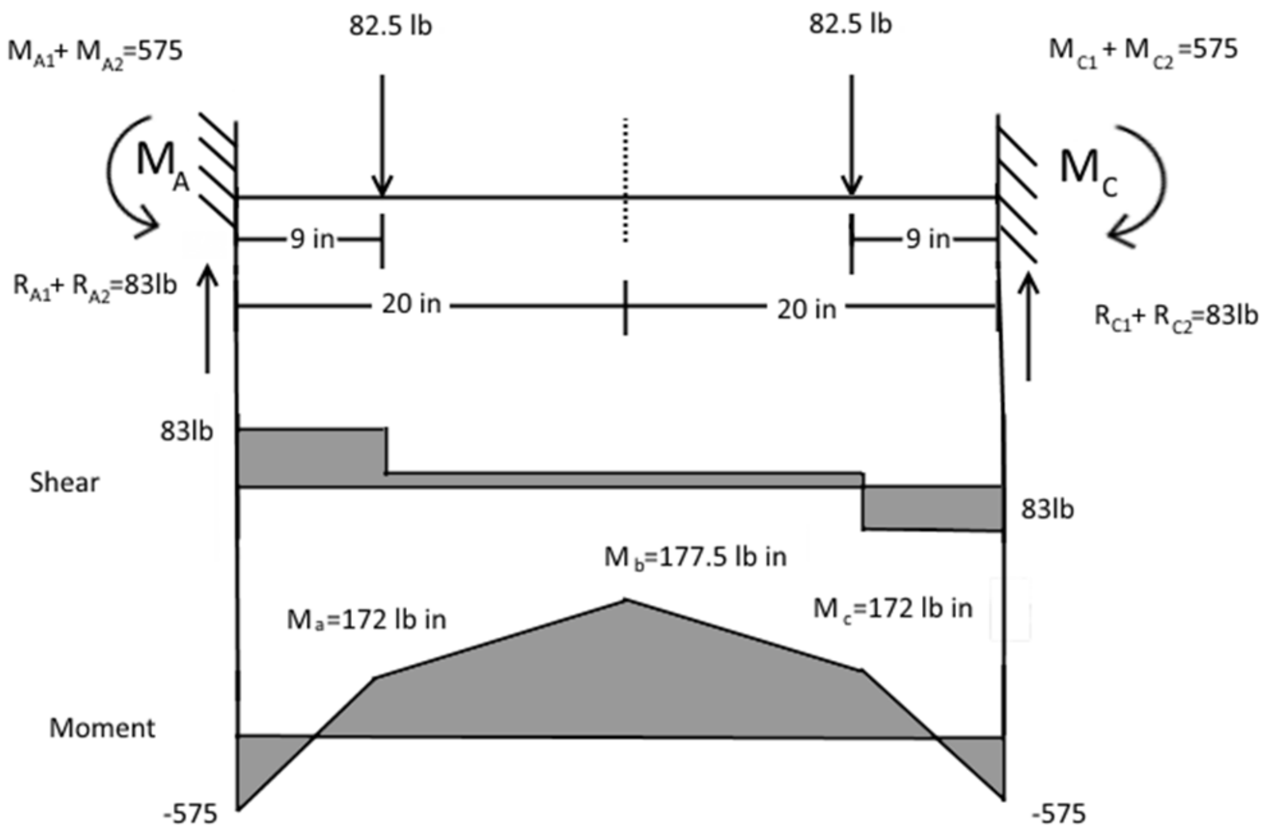


Figure 3 – Shear and moment diagram

Calculating for moment:

Ma = 83lb*9in – 575lb.in = 172lb.in

Mb = 83lb*20in – (82.5lb*11in) – 575lb.in = 177.5lb.in

Mc = 172lb.in

S>=Mmax / (allowable stress / N); (N = 3); (Southern yellow pine, the allowable stress = 1400lb/in^2)

S = (b*h^2) / 6, (Suppose b is equal to h)

S>= 575lb.in / (467lb/in^2) = 1.2in^3

b^3 = 7.2in^3

Take log for both side:

3*lnb = ln7.2

lnb = 0.66

b = 1.9in

(The cross sectional area of brace = 1.9in*1.9in = 3.61in^2, we choose the cross sectional area of brace is 1.5in*5.75in = 8.625in^2 > 3.61in^2. We have checked the stiffness, it is enough to the load.)

Diagrams and Drawings:

See Appendix C: Diagrams and Drawings.

Photographs:

See Appendix B: Photographs

Fabrication Procedure:

For the frame boards were cut to length and size from multiple 2x12x8' boards. Next 4x4x8' posts were cut in half to create the legs. The boards were attached to the legs via wood screws using 4 screws per attached board. The placement of the boards are shown in Figure 10 of appendix C.

For the grow bed, a dremel tool was used to cut down a plastic container to a height of 10 inches. Then a hole was drilled through the bottom of the container so that the bulwark could be assembled.

We decided to use a bell siphon for automatically draining the grow bed after the pump would flood it with water. We had to decide on a minimum water depth to leave in the bed (2 inches is recommended and what we chose), how much water to flood the bed with (we chose we wanted to pump 3 inches into the grow bed per cycle to leave 2/3 of the water in the fish tank below), and a diameter of drain pipe (we chose ¾ inch because it is the next larger size from our input of ½ inch from the pump). Therefore when we were making the siphon we needed a standpipe of 5 inches, a slotted outer cover with a height of 7 inches with 2 inch slots along the bottom, and a guard to keep the media from being sucked into the siphon.

The system is monitored and controlled by a raspberry pi B+. A relay board is used to control when the pump is turned on and off each hour and there are additional spots on the relay board for future expansion. A breadboard is used to connect the pH and temperature probes to the raspberry pi. The schematic for the electronics is shown in Figure 14 in Appendix C. The code is written in python and is founded and expanded from a program that reads the data from the sensors.

A water tight box was chosen to house the electronics and to provide power for the electronics. This is to be splash proof to protect the inside electronics. The power cord comes up through the bottom of the box and supplies power to the four outlets. Custom holders for the raspberry pi and relay board were made using Autodesk Inventor and printed on a 3d printer. The sensors and network cable run through a separate hole in the bottom of the box to prevent corruption from electrical feedback.

Figure 3 – Constant power.

The white outlets supply constant power. These are used to power the raspberry pi, switched on by the internal relay board the air pump, and the tank heater.

Figure 4 – Relay controlled power.

The brown outlets only supply power when And are marked by relay number. The outlet is currently used for the pump but will also be used to control the grow light.

The wiring schematic for the controls box is shown in Figure 13 of Appendix C.

Test Results:

The bell siphon and grow bed were tested by filling the grow bed with water. Once the water rose to a height exceeding 5 inches the siphon was supposed to activate and drain the water in the bed down to a height of 2 inches. The siphon activated as intended, achieving full siphon flow at a height of around 5.25 inches.

Electronics testing was conducted to make sure that we were receiving readings from our sensors and that they were being logged into our database. Air temperature was read and compared to a thermometer to find that the air probe was working properly. The pH sensor reading was compared to a pH test kit to ensure proper functioning. The electronics system was set up and the program was started to conduct testing. The program was supposed to activate the pump at every seventh minute after the hour (7, 14, 21…etc) and shut off the pump two minutes after turning on and to also turn the grow light on at 6am and off at 10pm. The program is controlling the pump and grow light as intended.

Fish tank cycling was the longest test procedure. Ammonia had to be added to the system until 5ppm is obtained. Every day the ammonia levels were checked until they dropped to 0ppm. Once the levels dropped to zero more ammonia was added to achieve 5ppm. Then testing for nitrites began. Once the nitrites and ammonia were dropping to around 0ppm in 24 hours then the tank was cycled and ready to add the fish. The plants were planted at this time but did not significantly grow because the system was not established yet. This was done to establish roots at this phase and start to use up the building amounts of nitrates because they are toxic to fish.

Current operating specs:

- 56GPH – within our 30 - 60GPH specifications
- pH 6.9 – within our 6.8 - 7.0pH specifications
- 81□F – within our 80 - 82□ specifications

Overall Cost:

The overall cost of the system was $757.27. For a detailed breakdown of components see Figure 16 in Appendix C.

Gannt Chart:

See Figure 17 of Appendix C.

Appendix A: References

"Aquaponics USA." Aquaponics Grow Beds. Aquaponics USA, n.d. Web. 19 Feb. 2017

"Bell Siphon Guide." Bell Siphon Guide. N.p., n.d. Web. 19 Feb. 2017.

Bernstein, Sylvia, and Dr. Wilson Lennard. "Aquaponics How To - The Aquaponic Source Rules of Thumb." The Aquaponic Source. The Aquaponic Source, n.d. Web. 19 Feb. 2017.

Bernstein, Sylvia. "Grow Bed Depth." The Aquaponic Source. N.p., 02 Aug. 2010. Web. 19 Feb. 2017.

Bolding, Dominic. "Connecting a PH Senstor to a Raspberry Pi." My Hydropi. Dominic Bolding, 13 May 2016. Web. 19 Feb. 2017.

"Successful Aquaponics Seed Starting | Terroir Seeds." Terroir Seeds | Underwood Gardens. Stephen Http://www.underwoodgardens.com/wp-content/uploads/2017/01/Terroir-Seedsheader12_29_15.jpg, 10 Feb. 2016. Web. 19 Feb. 2017.

"Tilapia Fingerlings and Tilapia Breeding Colonies." Lakeway Tilapia. Lakeway Tilapia, n.d. Web. 19 Feb. 2017.

Appendix B: Photographs

Photograph 1 – Stand pipe.

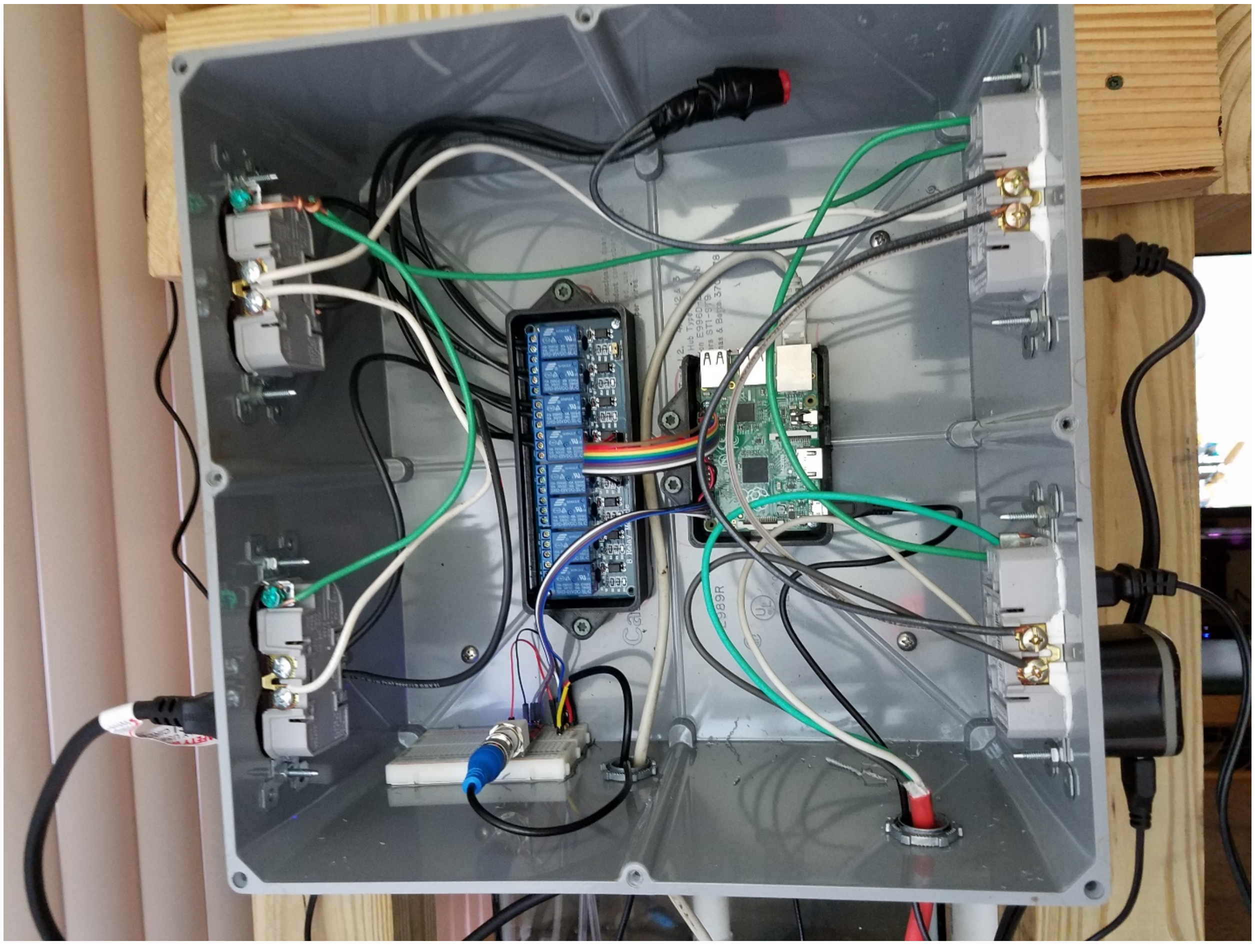
Photograph 2 – Outer bell and standpipe.

Photograph 3 – Guard, outer bell, and standpipe.

Photograph 4 – Frame, empty grow bed and tank.

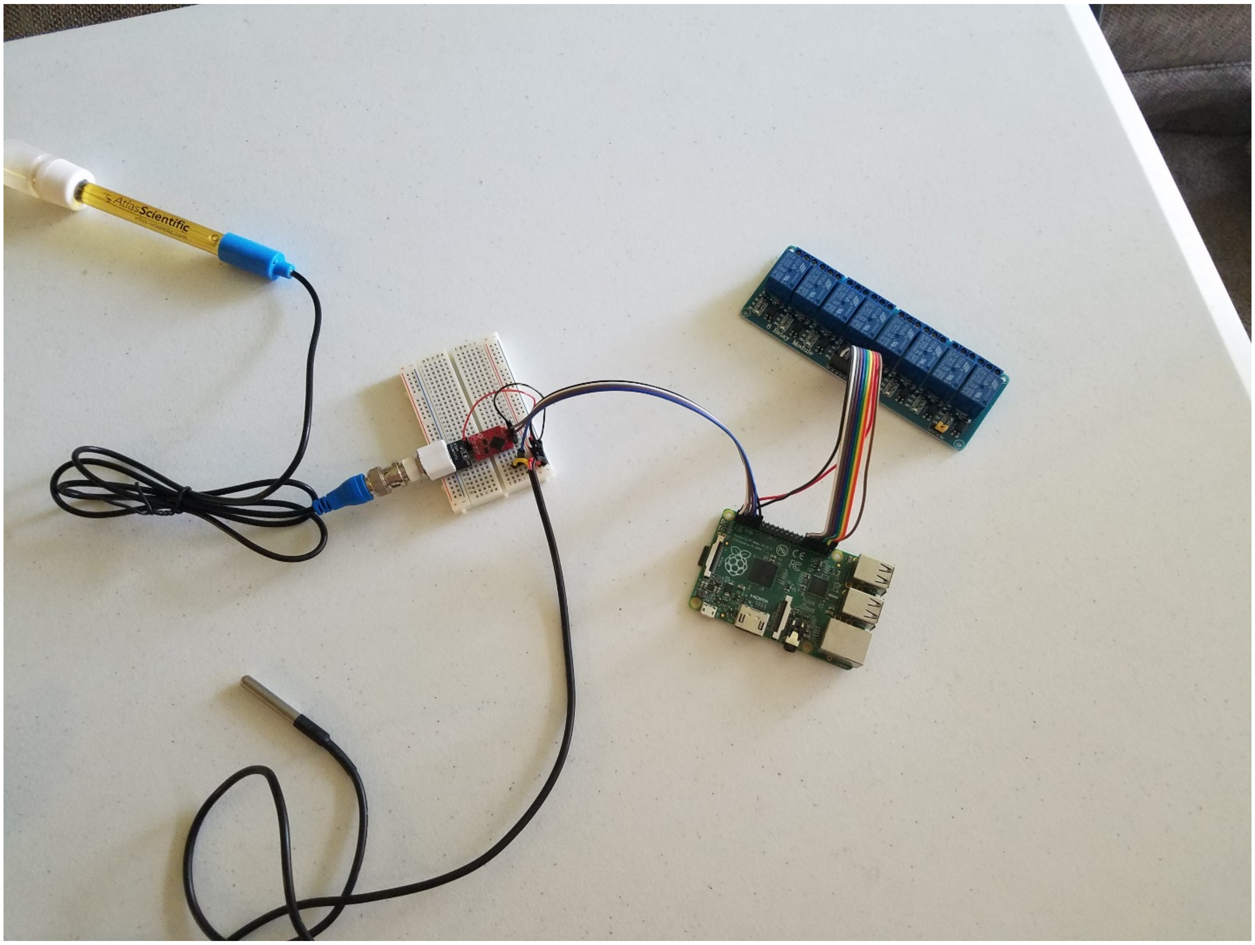
Photograph 5 – Filled grow bed.

Photograph 6 – Completed system.



Photograph 7 – Control box inside.

Photograph 8 – Control box outside.



Photograph 9 – Electronics assembled for testing.

Photograph 10 – Growing plants.

Photograph 11 – Healthy fish.

Appendix C: Diagrams and Drawings

- Bell Siphon

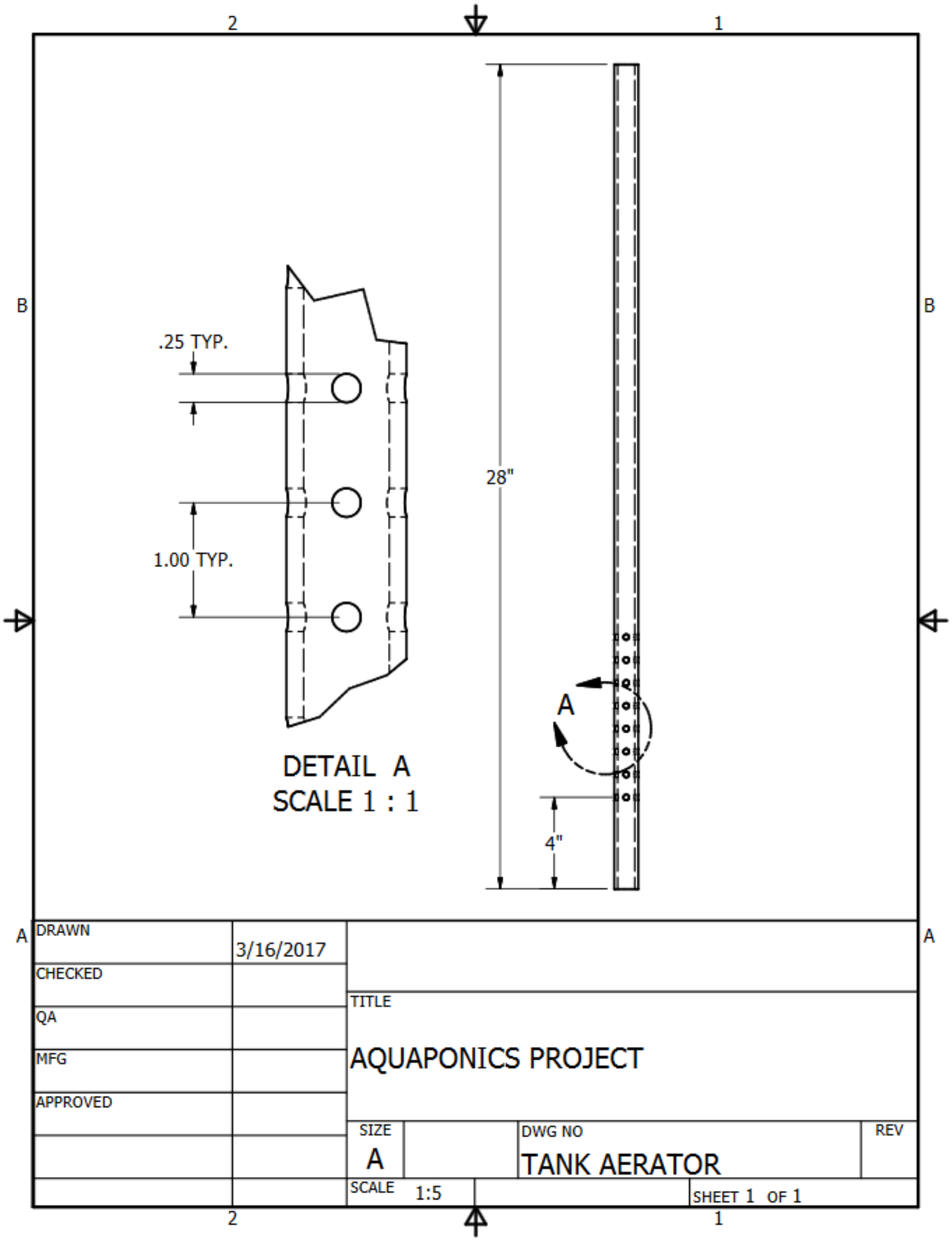


Figure 5 – Aerator.

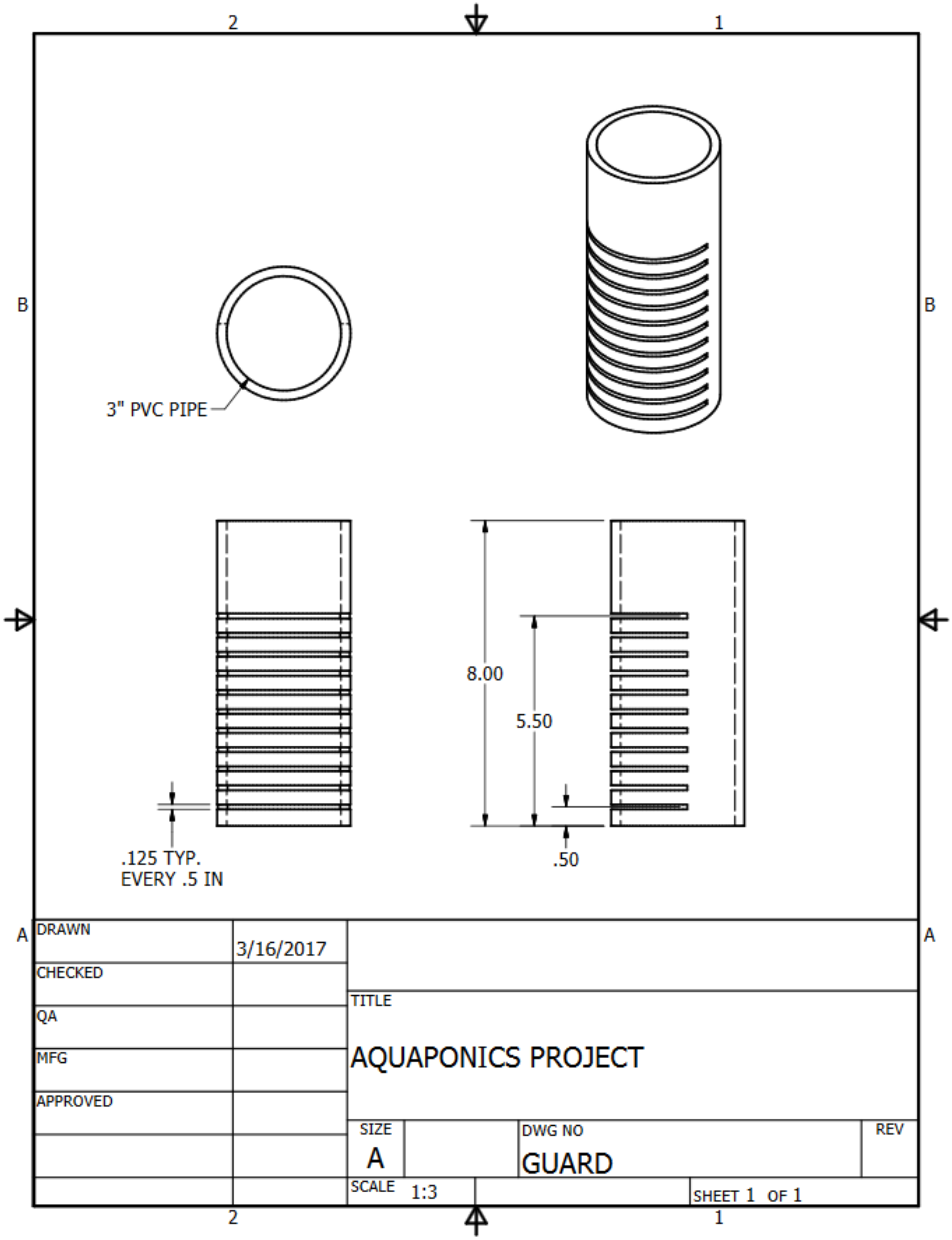


Figure 6 – Bell guard.

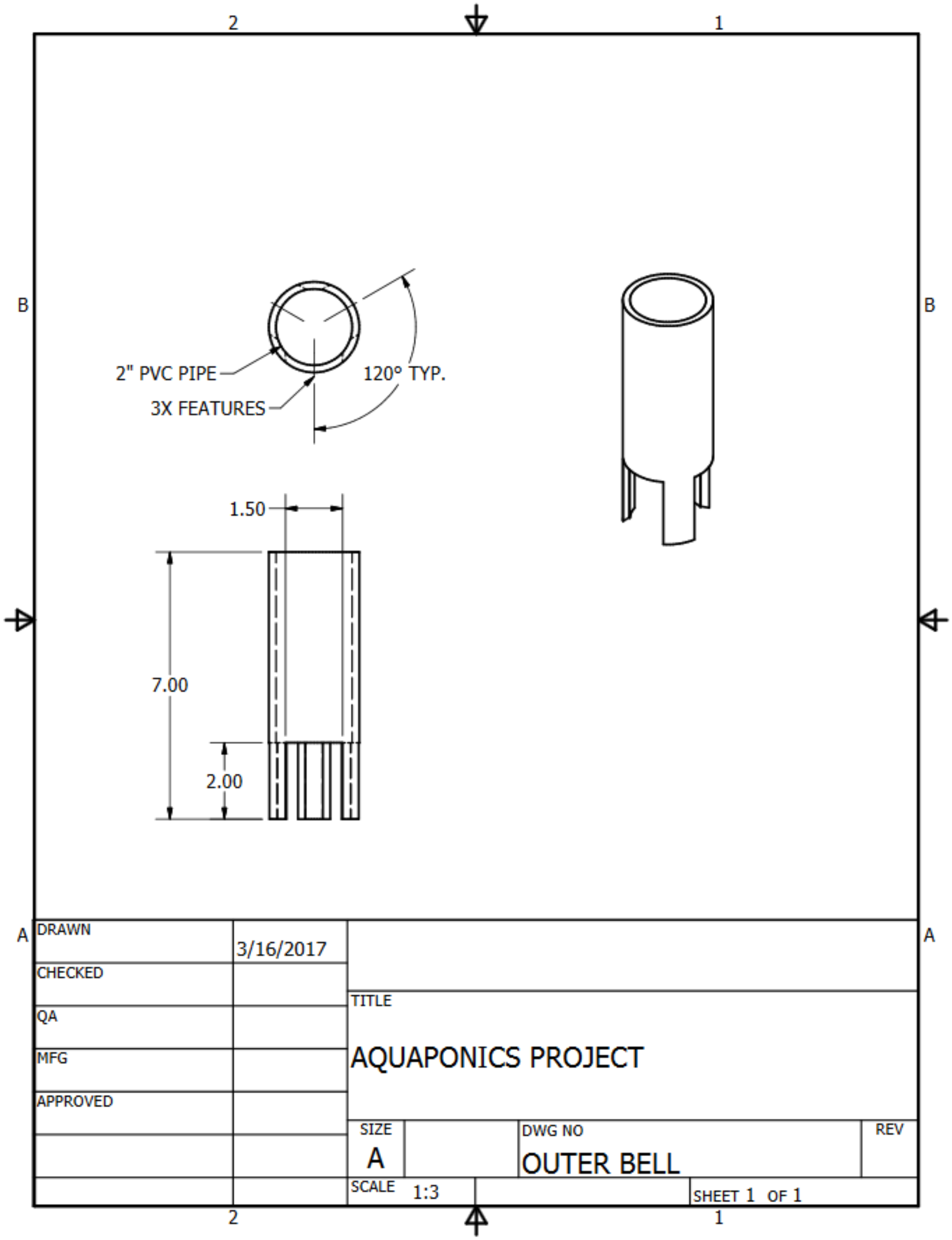


Figure 7 – Outer bell.

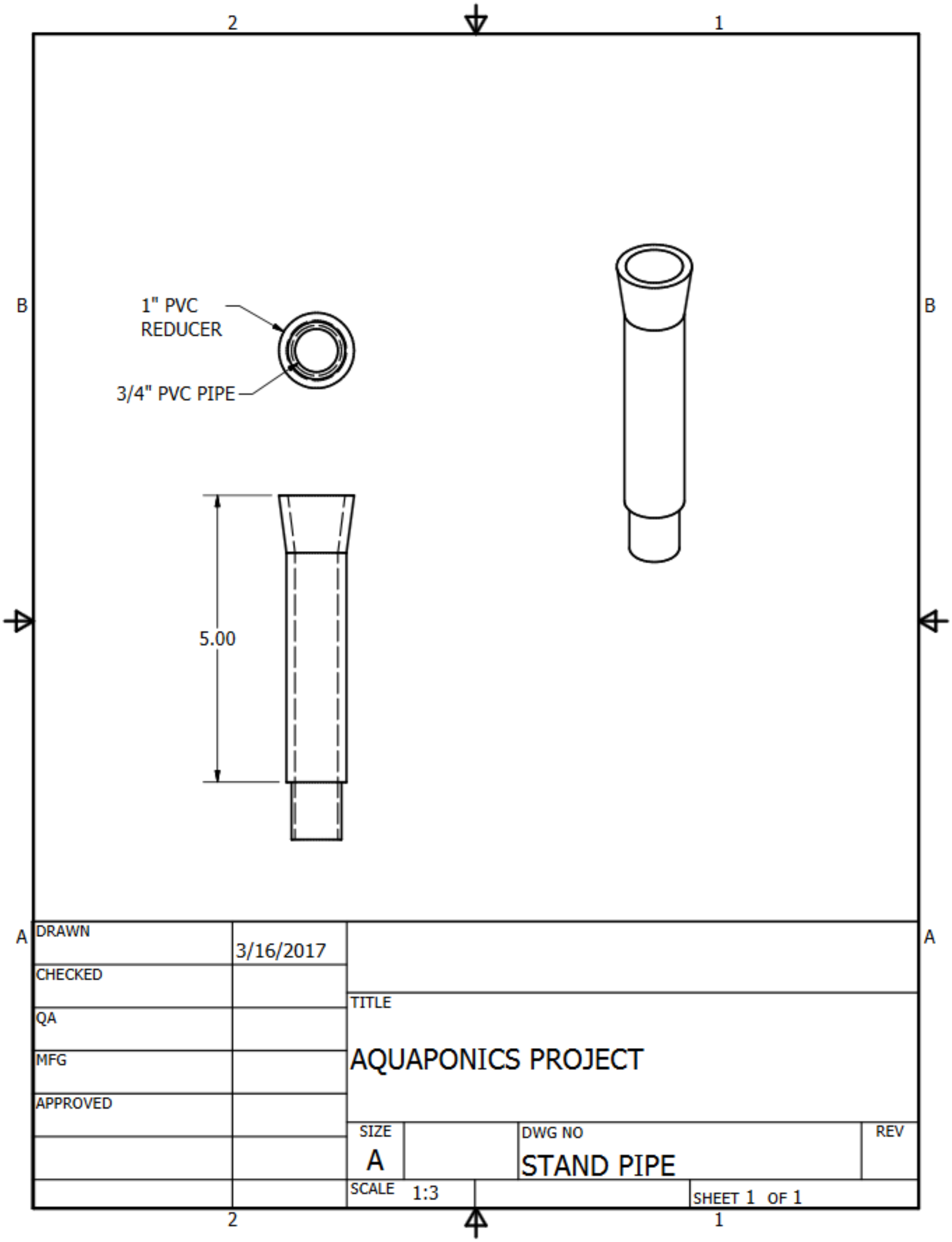


Figure 8 – Standpipe.

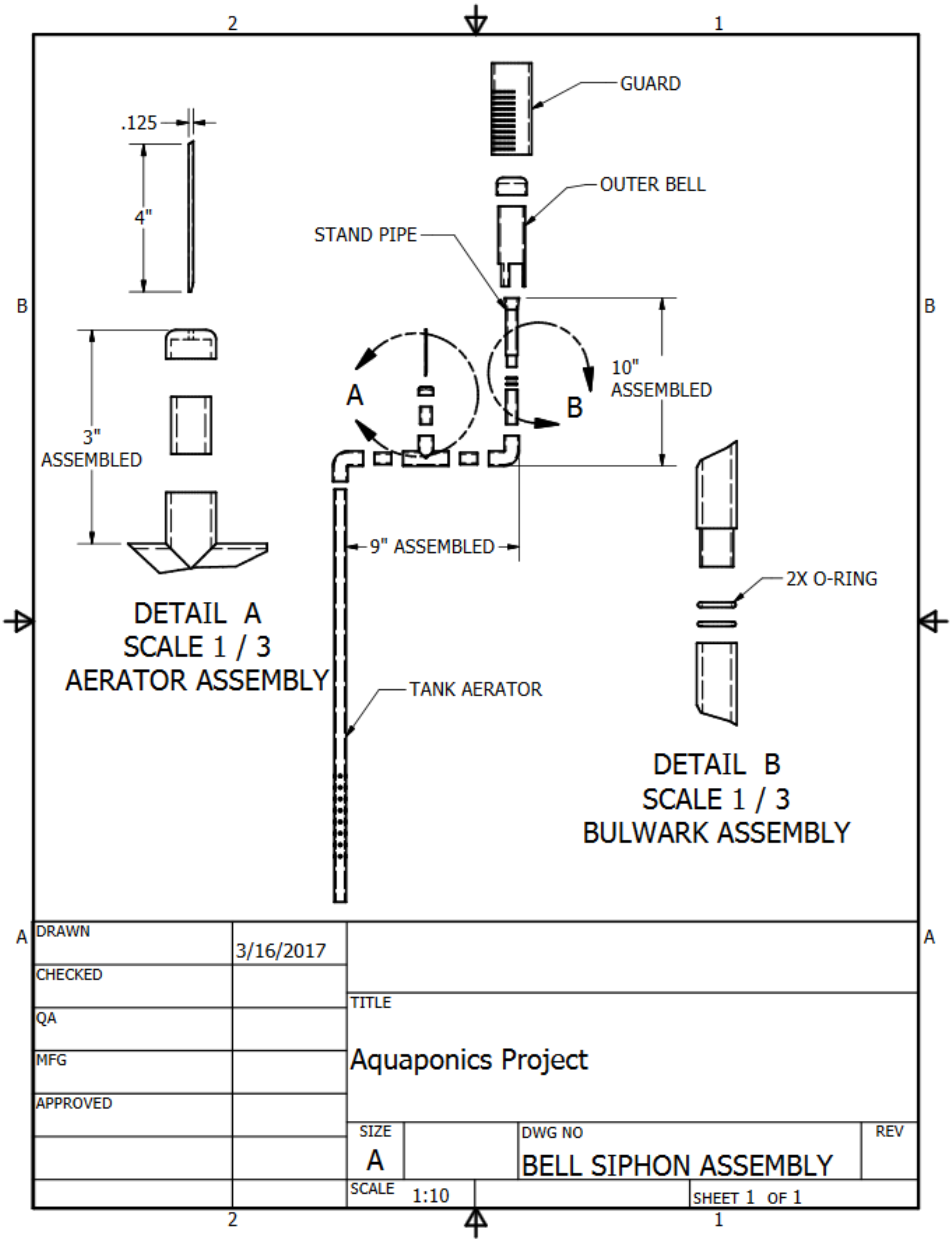


Figure 9 – Bell siphon assembly.

- Frame

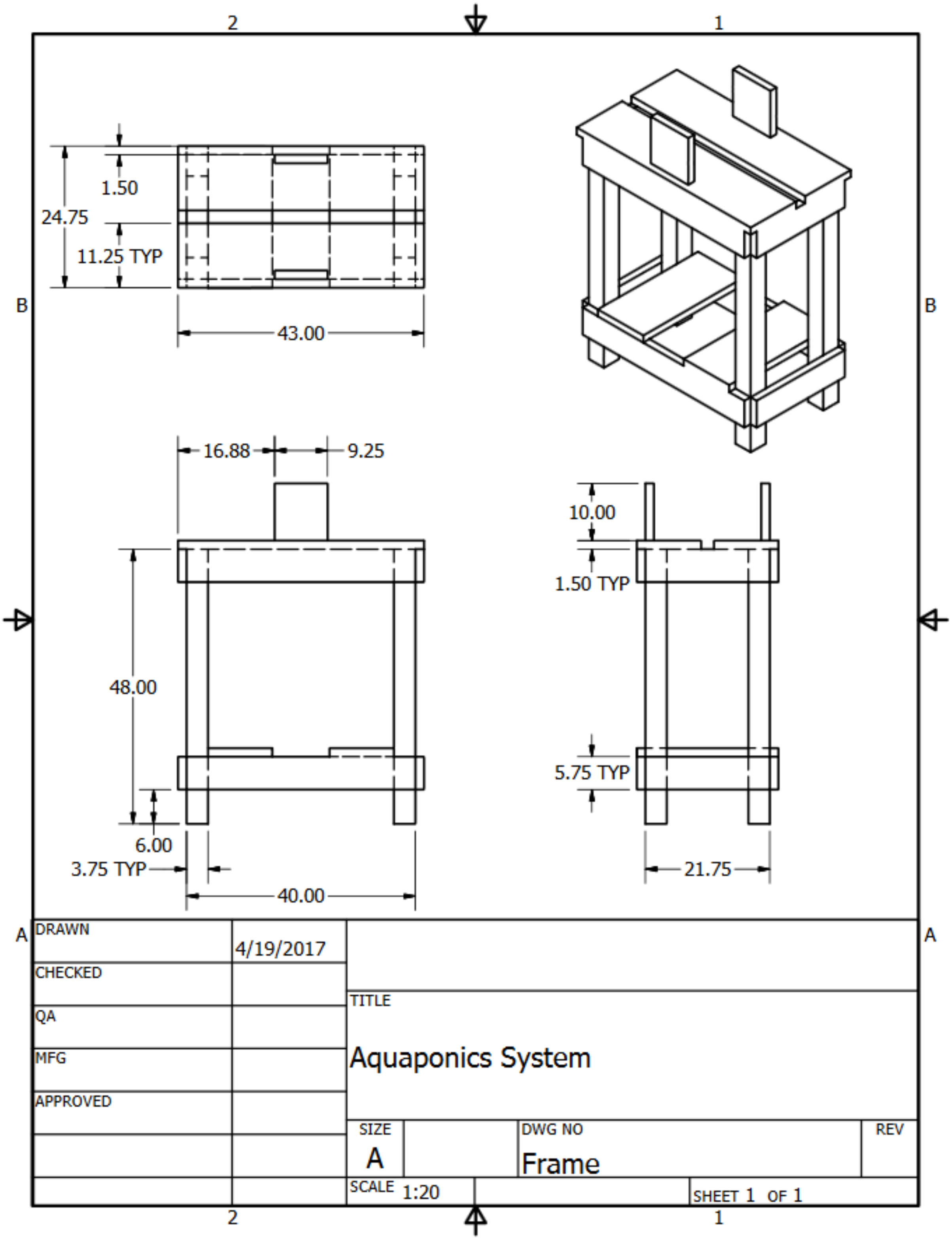


Figure 10 – Frame.

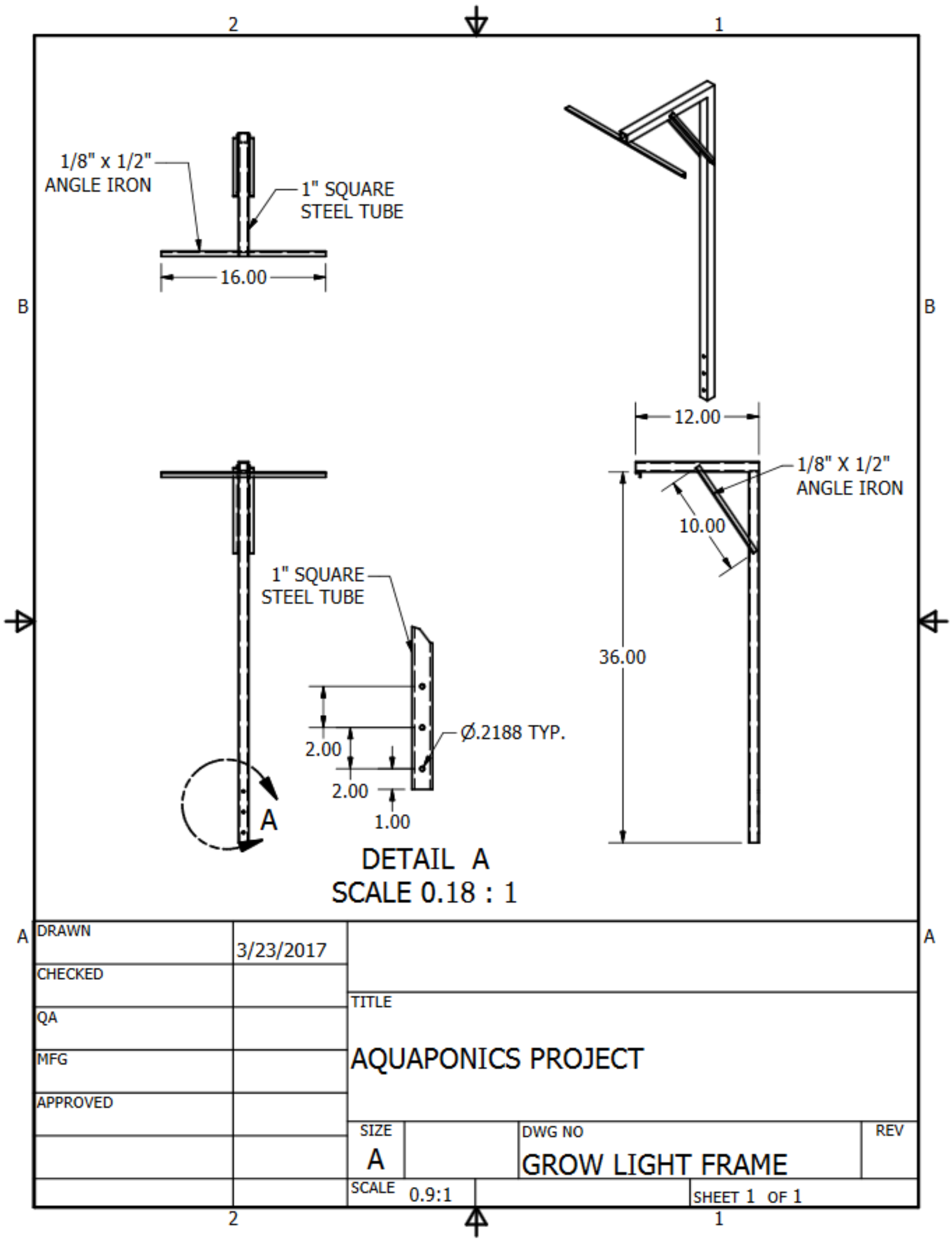


Figure 11 – Grow light frame.

- Grow Bed

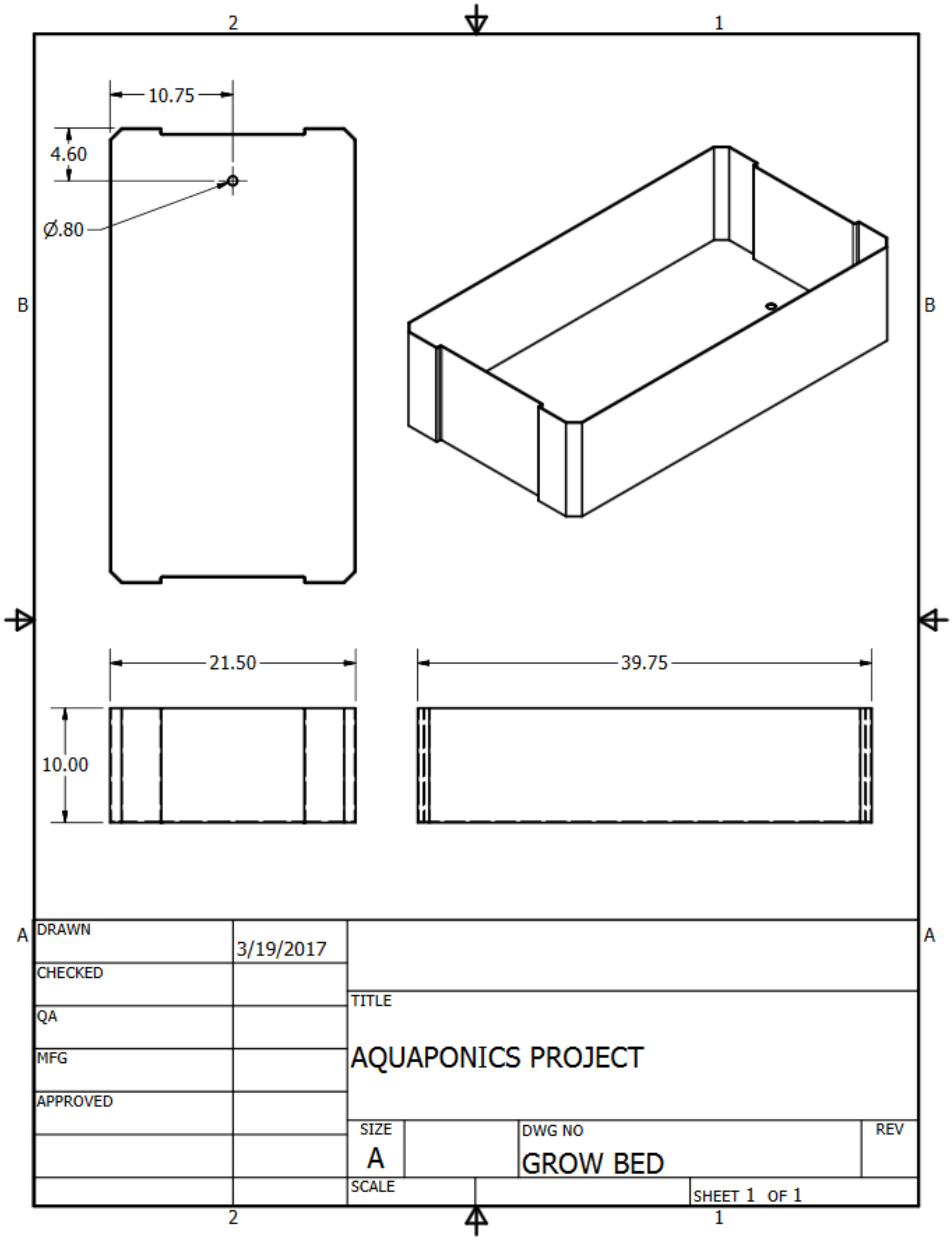


Figure 12 – Grow bed.

- Schematics

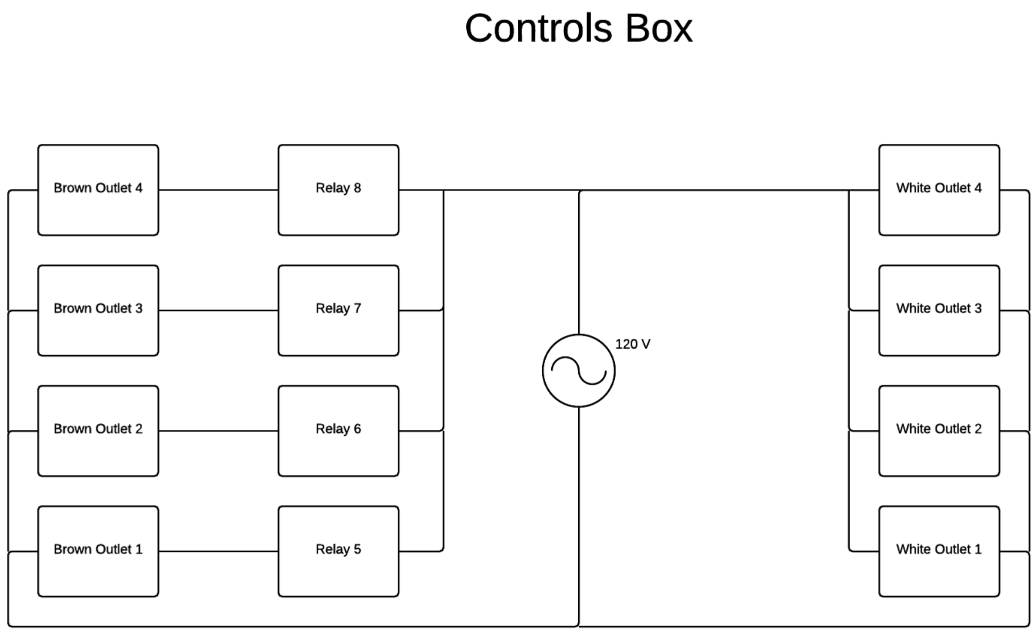


Figure 13 – Control Box connections.

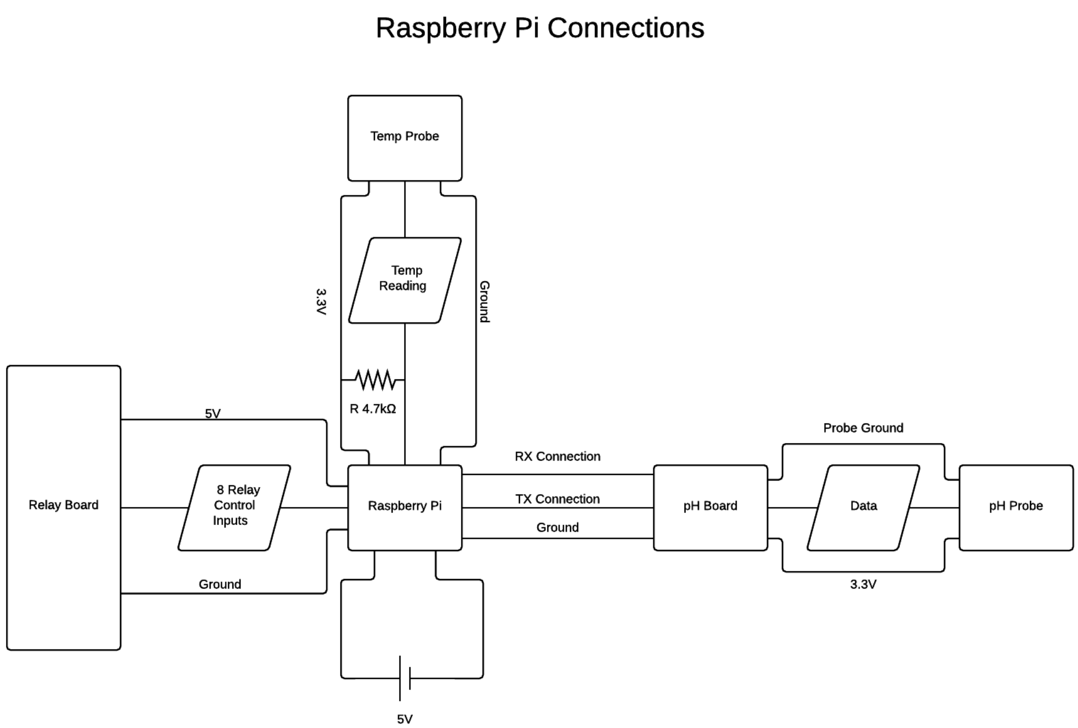


Figure 14 – Electronics connections.

Flow of Water

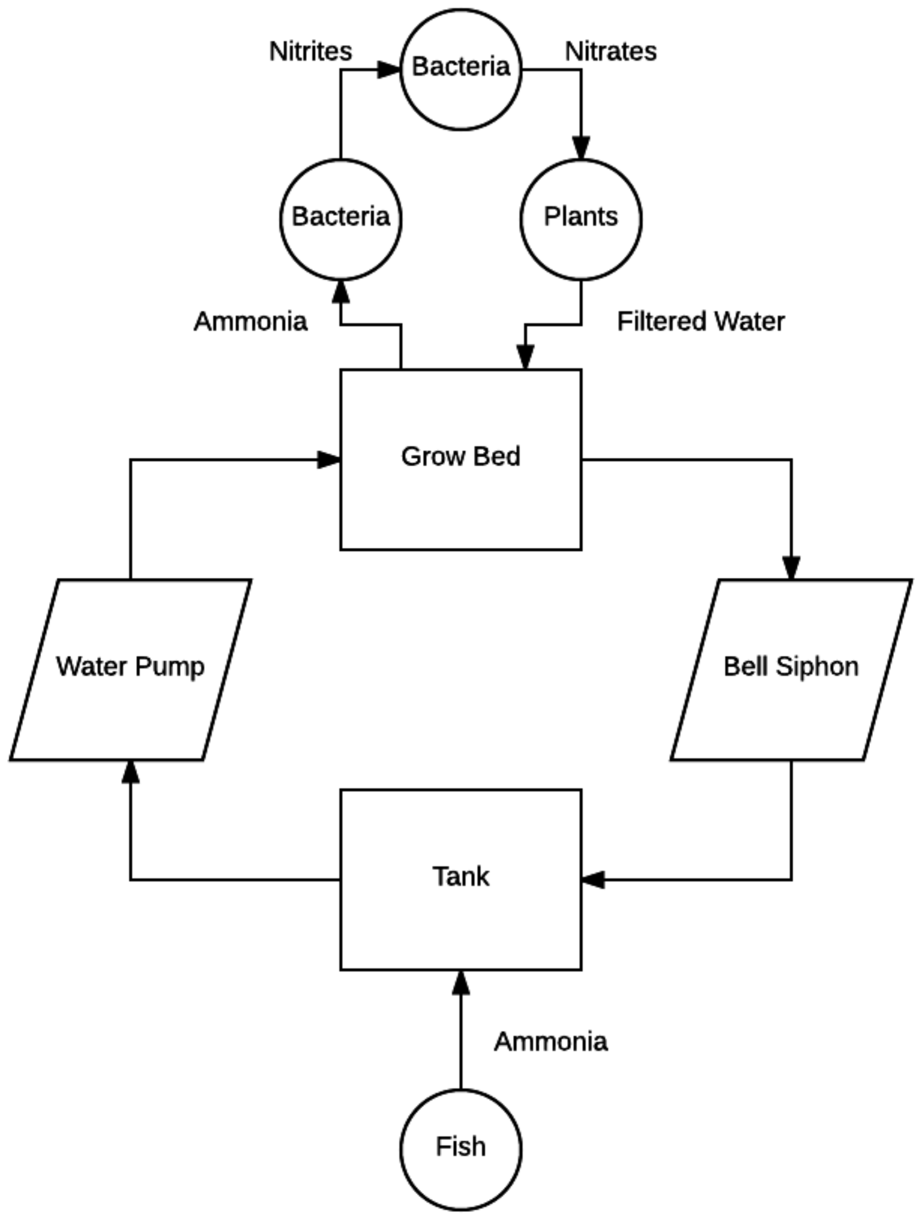


Figure 15 – Flow cycle.

- Bill of Materials

BILL OF MATERIALS				
QUANTITY	DESCRIPTION	SOURCE	COST(PER)	TOTAL
1	Raspberry Pi B+	Adafruit	$29.95	$29.95
1	pH Sensor	Amazon	$72.00	$72.00
1	pH Sensor Connector	Amazon	$13.00	$13.00
4	25L LECA Clay Grow Media	Amazon	$25.61	$102.44
13	Jumper Wire	Amazon	$0.07	$0.91
1	Ponics Pump 211GPH	Amazon	$18.99	$18.99
1	Breadboard	Amazon	$8.90	$8.90
1	Temp Probe DS18B20	Amazon	$11.90	$11.90
1	ph Sensor Board	Amazon	$38.00	$38.00
1	8 Channel Relay Board	Amazon	$8.98	$8.98
1	29 gal tank	Amazon	$78.29	$78.29
1	4.7kΩ Resistor	Amazon	$0.08	$0.08
1	T5 Grow Light	Amazon	$60.22	$60.22
1	2.4A Cell Phone Charger	Best Buy	$14.99	$14.99
2	Pressure Treated Southern Pine 4 x 4 x 8'	Home Depot	$8.17	$16.34
3	Southern Pine 2 x 12 x 8'	Home Depot	$9.66	$28.98
10	Tilapia	Lakeway Tilapia	$3.00	$30.00
65	PrimeGuard Coated Exterior Screws	Lowe's	$0.07	$4.55
1	3" x 2' PVC Pipe	Lowe's	$4.08	$4.08
1	2" x 2' PVC Pipe	Lowe's	$4.96	$4.96
2	3/4" x 5' PVC Pipe	Lowe's	$2.07	$4.14
2	3/4" 90 Elbow	Lowe's	$0.93	$1.86
1	2" PVC Cap	Lowe's	$2.08	$2.08
2	1/2" Rubber O-Ring	Lowe's	$1.33	$2.66
1	1/2" ID x 4' PVC Tubing	Lowe's	$2.30	$2.30
1	3/4" Threaded PVC Coupling Male	Lowe's	$0.38	$0.38
1	3/4" Threaded PVC Coupling Female	Lowe's	$0.63	$0.63
2	Brown Double Outlet	Lowe's	$1.19	$2.38
1	3/4" PVC Tee Couple	Lowe's	$0.50	$0.50
1	1" - 3/4" Reducer	Lowe's	$1.00	$1.00
8	1' 14 AWG Wire	Lowe's	$0.26	$2.08
2	3/8" NM/SE Connector	Lowe's	$0.30	$0.60
1	10' 14 AWG Extension Cord	Lowe's	$13.97	$13.97
1	Tomato Seed Packet	Menards	$0.35	$0.35
1	PVC Enclosure	Menards	$34.61	$34.61
2	White Double Outlet	Menards	$1.19	$2.38
1	Square Tube 1"	Menards	$11.49	$11.49
1	Angle Iron 1/8" x 1/2"	Menards	$5.87	$5.87
1	Test Kit	PetSmart	$30.49	$30.49
1	Tank Heater	Uncle Bill's Pet Store	$37.99	$37.99
1	Air Pump	Uncle Bill's Pet Store	$18.99	$18.99
1	Air Tubing	Uncle Bill's Pet Store	$3.99	$3.99
1	12" Airstone	Uncle Bill's Pet Store	$4.99	$4.99
1	Air Tubing Holder	Uncle Bill's Pet Store	$3.99	$3.99
1	Clear Latch Box	Walmart	$19.99	$19.99
			TOTAL	$757.27

Figure 16 – Bill of materials.

- Gannt Chart

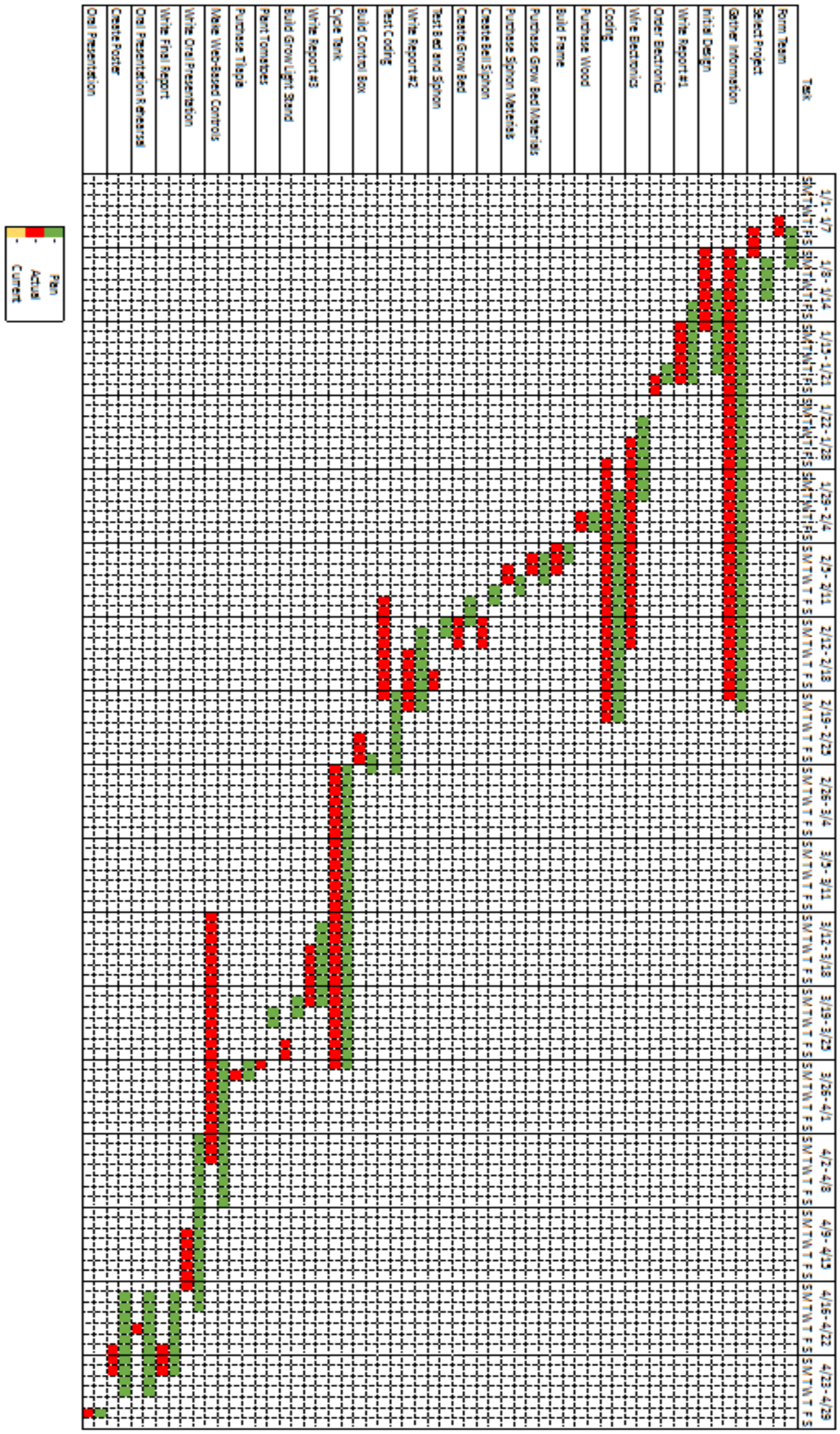


Figure 17 – Gannt chart.