SRP EVAP

ME 476C Spring 2025

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CAD & Schematics

Figure 1: CAD View 1

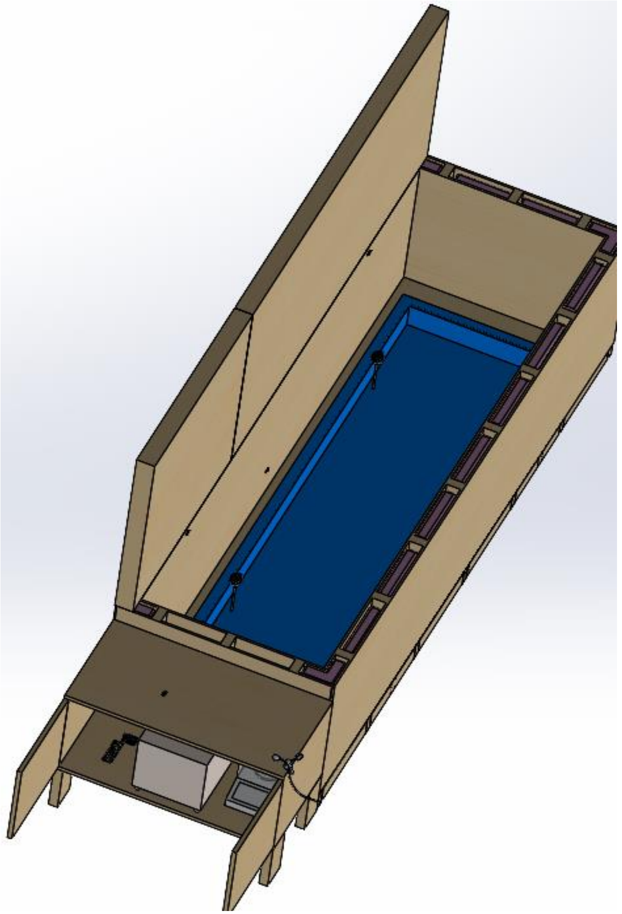


Figure 2: CAD View 2

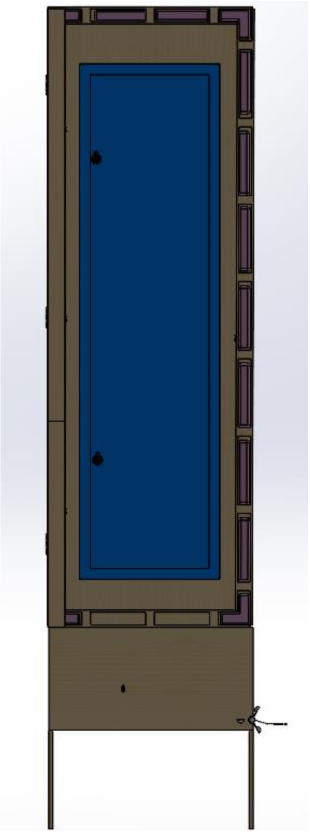
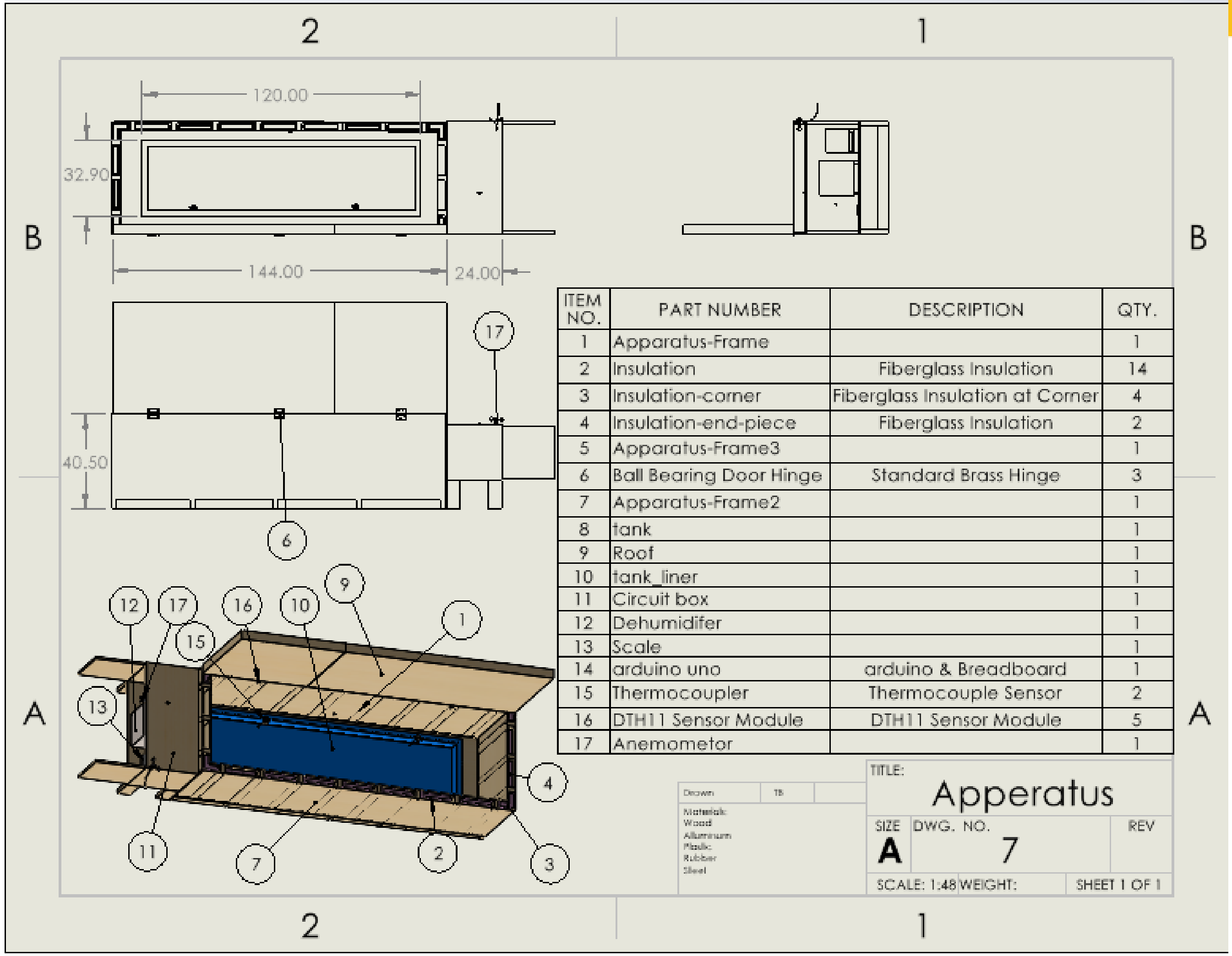


Figure 3: CAD View 3

Trey Bushling, 10/13/25, SRP EVAP

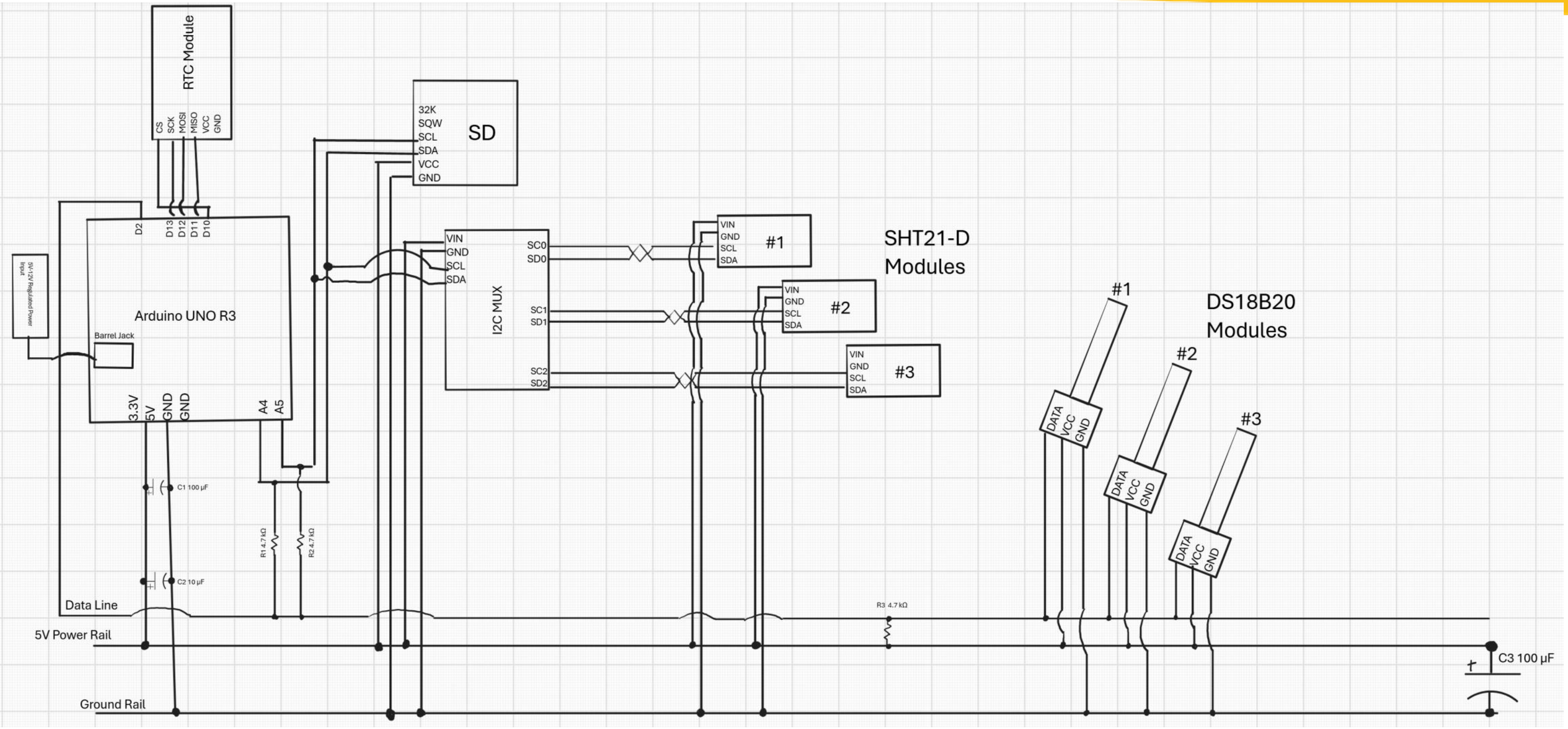
CAD & Schematics



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Apparatus-Frame		1
2	Insulation	Fiberglass Insulation	14
3	Insulation-corner	Fiberglass Insulation at Corner	4
4	Insulation-end-piece	Fiberglass Insulation	2
5	Apparatus-Frame3		1
6	Ball Bearing Door Hinge	Standard Brass Hinge	3
7	Apparatus-Frame2		1
8	tank		1
9	Roof		1
10	tank_liner		1
11	Circuit box		1
12	Dehumidifer		1
13	Scale		1
14	arduino uno	arduino & Breadboard	1
15	Thermocoupler	Thermocouple Sensor	2
16	DTH11 Sensor Module	DTH11 Sensor Module	5
17	Anemometor		1

Figure 4: Drawing

Circuit Diagram



Garet Bowels, 10/13/25, SRP EVAP

Updated Design Efforts & Engineering Calculations

1. New characteristic length for the 1:5 rectangle sample area of Grand Canal in Pheonix:

$$L_c = \frac{A_s}{P}$$

$$L_c = \frac{37.6m^2}{32.9m} = 1.143m$$

2. Rayleigh number calculation with new characteristic length:

$$Ra_m = Gr_m \cdot Sc = \left[\frac{g(\rho_s - \rho_\infty)L_c^3}{\rho_\infty \cdot \nu^2}\right] \cdot \frac{\nu}{D_{AB}}$$

$$Ra_m = \left[\frac{9.81\frac{m}{s^2}\left(1.151\frac{kg}{m^3} - 1.142\frac{kg}{m^3}\right)(1.143m)^3}{1.142\frac{kg}{m^3}\left(15.236 \times 10^{-6}\frac{m^2}{s}\right)^2}\right] \cdot 0.632 = 3.143 \times 10^8$$

3. Rayleigh number for apparatus with 1:5 rectangle water tank:

$$Ra_m = \left[\frac{9.81\frac{m}{s}\left(1.262\frac{kg}{m^3} - 1.138\frac{kg}{m^3}\right)(0.254m)^3}{1.262\frac{kg}{m^3}\left(15.255 \times 10^{-6}\frac{m^2}{s}\right)^2}\right] \cdot 0.633 = 4.31 \times 10^7$$

4. Difference in Rayleigh numbers using the previous characteristic length:

$$\left(5.14 \times 10^{11}\right) - \left(7.76 \times 10^{10}\right) = 4.36 \times 10^{11}$$

5. Difference in Rayleigh numbers using the updated characteristic length:

$$\left(3.14 \times 10^{8}\right) - \left(4.31 \times 10^{7}\right) = 2.71 \times 10^{8}$$

$$2.71 \times 10^8 \ll 4.36 \times 10^{11}$$

Updated Design Efforts & Engineering Calculations

Additionally, a smaller Rayleigh (and Grashof) number allows us to use a Sherwood correlation produced from a published mass transfer experiment to begin modelling a convective mass transfer coefficient.

$$\overline{Sh} = 0.15(Ra_m)^{\frac{1}{3}} = 0.15\left(3.143 \times 10^8\right)^{\frac{1}{3}} = 101.986$$

With a Rayleigh number range of: $\left(8 \times 10^6 \leq Ra \leq 1.6 \times 10^9\right)$

$$\bar{h}_m = \frac{\overline{Sh} \cdot D_{AB}}{L_c} = \frac{101.986\left(2.41 \times 10^{-5}\,\frac{m^2}{s}\right)}{1.143m} = 0.00215\frac{m}{s}$$

This convective mass transfer coefficient could be used as a reference to check if we are taking data under the correct conditions.

Source: *Natural Convection Adjacent to Horizontal Surface of Various Planforms*
Lloyd, J. R., and W. R. Moran, J. Heat Transfer, 96, 443, 1974.

Design parameters to achieve the Rayleigh number:
$T_\infty = 45°F$
$T_s = 90°F$
$\phi = 2\%$
$L_c = \frac{A_s}{P} = 0.254m$

In Conclusion:

- New characteristic lengths produced smaller Rayleigh numbers
- This allowed us to use a previously published Sherwood correlation to model a convective mass transfer coefficient which we can reference during our own data collection
- The temperature and relative humidity conditions in the apparatus have not changed

Testing Plan Summary

Ambient Open Conditions

- Ambient Air Temp
- Ambient Water Temp
- Ambient Humidity
- **Exposed Ceiling**

Controlled Humidity Conditions

- Ambient Air Temp
- Ambient Water Temp
- **2% Humidity**
- Enclosed Ceiling

Controlled Water Temperature

- Ambient Air Temp
- **32.22$^{\circ}C$ Water Temp**
- Ambient Humidity
- Exposed Ceiling

Ambient Closed Conditions

- Ambient Air Temp
- Ambient Water Temp
- Ambient Humidity
- **Enclosed Ceiling**

Controlled Air Temperature

- **7.22$^{\circ}C$ Air Temp**
- Ambient Water Temp
- Ambient Humidity
- Enclosed Ceiling

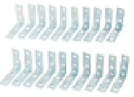
"Ideal Scaled" Conditions

- **7.22$^{\circ}C$ Air Temp**
- **32.22$^{\circ}C$ Water Temp**
- **2% Humidity**
- Enclosed Ceiling

Bill of Materials

- Link to BOM

[Fall BOM.xlsx]

2025 Bill Of Materials						
Component:	Quantity:	Description:	Total Price:	Acquisition Method:	Primary Vendor:	Images
Purchased:						
Plywood	10	48in x 96in plywood for the walls	$ 149.80	Bought	Home Depot	
Wood Beams	20	2in x 3in x 96in wood beams to hold ply wood and to separate insulation	$ 59.60	Bought	Home Depot	
#8 2in Flat head Philips exterior screws	5 lb pk of 672	2in screws to hold plywood and wood beams together	$ 33.39	Bought	Home Depot	
2" Corner Brace Zinc 3X 20pk	60	Braces for the walls of the apparatus	$ 44.91	Bought	Home Depot	
#6 3/4in Flat Head Philips metal to wood screws	200	Connecting the braces to the wood	$ 23.92	Bought	Home Depot	
Waterproof floor putty	1	For waterproofing and sleaing screws	$ 6.97	Bought	Home Depot	

Purchasing Plan

Part	Quantity Needed	Purchase Quantity	Current Quantity	Unit Price ($)	Total Price ($)	Order Placed (Y/N)
Plywood	15	0	15	14.98	224.7	Y
Wood Beams	35	0	35	2.98	104.3	Y
#8 2in Flat head Philips exterior screws (5lb pk of 6720)	1	0	1	33.39	33.39	Y
2" Corner Brace Zinc 20pk	4	0	4	14.97	59.88	Y
#6 3/4in Flat Head Philips metal to wood screws (50 pk)	4	0	4	5.98	23.92	Y
Waterproof floor putty	1	0	1	6.97	6.97	Y
5" x 5" Zinc T-Plate	12	0	12	2.86	34.32	Y
Insulation	2	0	2	20.67	41.34	Y
Reptile Humidity & Thermometer	2	0	2	6.99	13.98	Y
Digital Water Thermometer	2	0	2	11.99	23.98	Y
Plastic Water Container	3	0	3	4	12	Y
Hot Glue Sticks	2	0	2	3	6	Y
1500W Water Heater	1	1	0	104.5	104.5	Y
LED Detachable Tripod Light	2	2	2	24.88	49.76	Y
Wall & Cavity Foam	1	0	1	199.98	199.98	Y
Wide Spray Foam Sealant	4	0	4	39.98	159.92	Y
Arduino	1	0	1	0	0	Y
Vinyl Pool liner	1	0	1	104.97	104.97	Y
Hinges	3	0	3	10.47	31.41	Y
Silicone Caulk	5	0	5	6.89	34.45	Y
Caulk Gun	1	0	1	11.98	11.98	Y
Construction Mask	6	0	6	2	12	Y
4mm Rubber Gloves (200 count)	2	0	2	13	26	Y
GFCI Outlet box	3	0	2	10.48	31.44	
Desiccant	1	0	1	215	215	Y
Glass Siphon Receiving Dish	1	0	0	0	0	N
Scientific Balance	1	0	1	157	157	Y
Rubber Siphon Tube	1	0	0	0	0	N

Purchasing Plan Continued

GFCI Outlet	3	0	3	15.51	46.53	Y
Insulation Spray Foam Adhesive Guru	1	0	1	169.99	169.99	Y
Arduino Sensors	6	0	6	10.93	65.58	Y
Electrical Box For Arduino	1	0	1	12.99	12.99	Y
Flat Brackets	10	0	10	4.72	47.2	Y
Rubber Fridge Liner	1	0	1	19.99	19.99	Y
Heavy Duty Tarp	1	0	1	77.97	77.97	Y
Weather Proof Coating	1	0	1	22.5	22.5	Y
Paint Brush	3	0	3	1.87	5.61	Y
Paint Holder	2	0	2	0.98	1.96	Y
Dehumidifyer	1	1	0	393	393	Y
Arduino Loading Cells	4	4	0	15.99	15.99	Y
Weather Proof Paint	2	0	0			N
				Total Spent ($):	2602.5	

Total Spent
No Change from Previous Update
Updated Status
Planned But Not Purchased

Manufacturing Plan

Part	Time [hours]	Manufacturing Method	Progress Percentage
Apparatus Base, Walls, & Roof	60	Woodworking/Assembly	100%
Data Collection Circuit	15	Electronics/Wiring	85%
Water Pool	6	Woodworking/Lining	100%
Air temp. & humidity control system	5	Installation/Mounting	20%
Sensor Mounting and Calibration	5	Calibration	85%
Siphon for Water Level & Balance Calibration	1.5	Tubing/Calibration	20%
Total	**92.5**		**68.33%**

Table 2: Manufacturing Plan

SHT21-D Calibration Verification

SHT21-D

Relative Humidity

Parameter	Condition	Value	Units
Resolution [1]	12 bit	0.04	%RH
	8 bit	0.7	%RH
Accuracy tolerance [2]	typ	±2	%RH
	max	see Figure 2	%RH
Repeatability		±0.1	%RH
Hysteresis		±1	%RH
Nonlinearity		<0.1	%RH
Response time [3]	τ 63%	8	s
Operating Range	extended [4]	0 to 100	%RH
Long Term Drift [5]	Typ.	< 0.25	%RH/yr

Temperature

Parameter	Condition	Value	Units
Resolution [1]	14 bit	0.01	°C
	12 bit	0.04	°C
Accuracy tolerance [2]	typ	±0.3	°C
	max	see Figure 3	
Repeatability		±0.1	°C
Operating Range	extended [4]	-40 to 125	°C
Response Time [7]	τ 63%	5 to 30	s
Long Term Drift [8]	Typ.	< 0.02	°C/yr

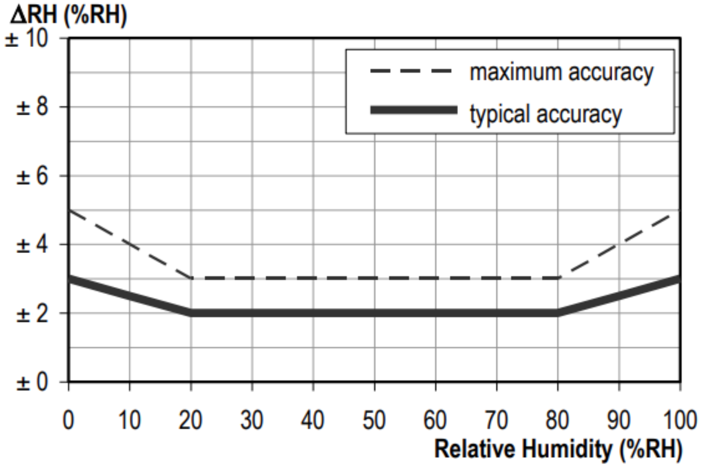


Figure 5: Performance Curve for %RH

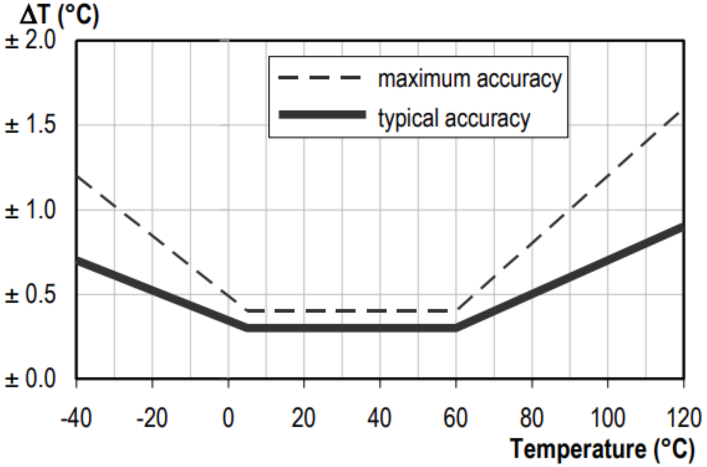


Figure 6: Performance Curve for Temperature

Relative Humidity

- Mean Error: ±2 % RH
- Max Error: ±5 % RH
- Expecting a little error due to our low %RH needed

AIR Temperature (°C)

- Mean Error: ± 0.3 °C
- Max Error: ± 1-1.5 °C
- Error is limited due to our expected temperatures used

DS18B20 Calibration Verification

DS18B20

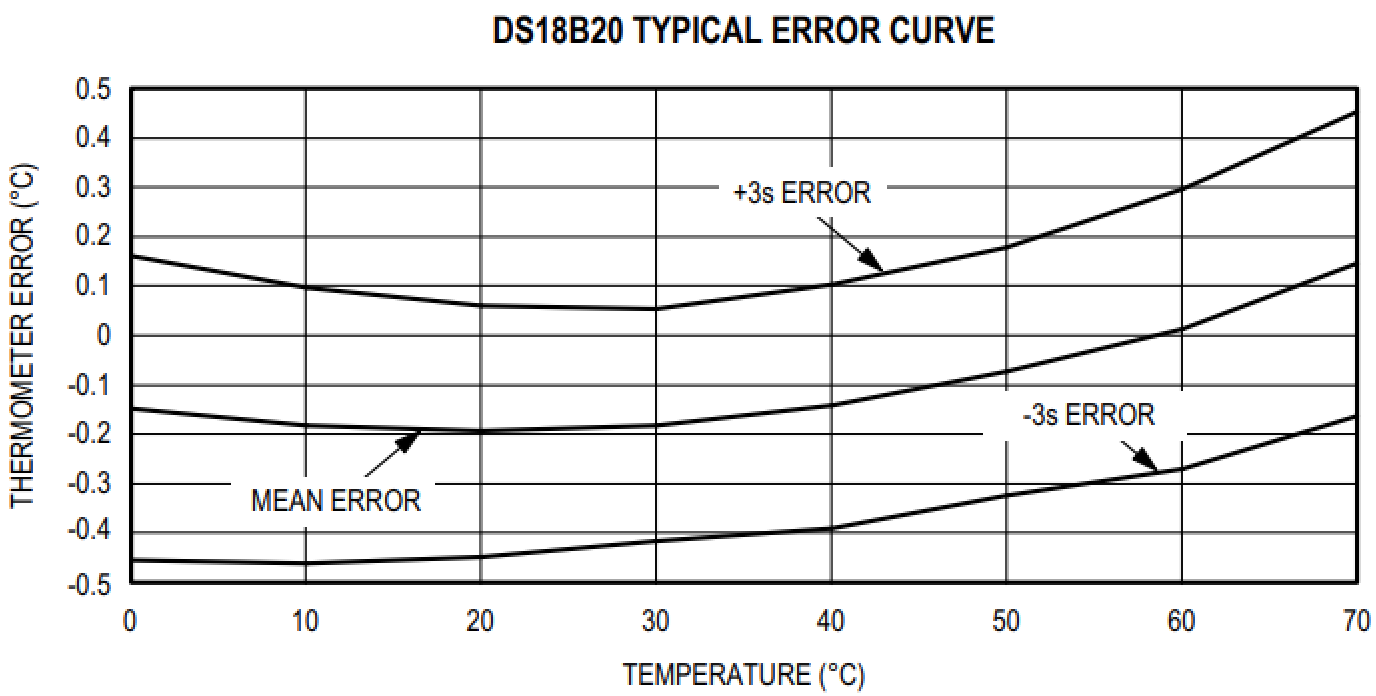


Figure 7: Performance Curve for Water Temp Sensor

Water Temperature (°C)

- Mean Error: ± 0.2 °C
- Standard Deviation: ±3 ≈ ±0.5°C
- Stable accuracy within our temp ranges 8°C – 40 °C

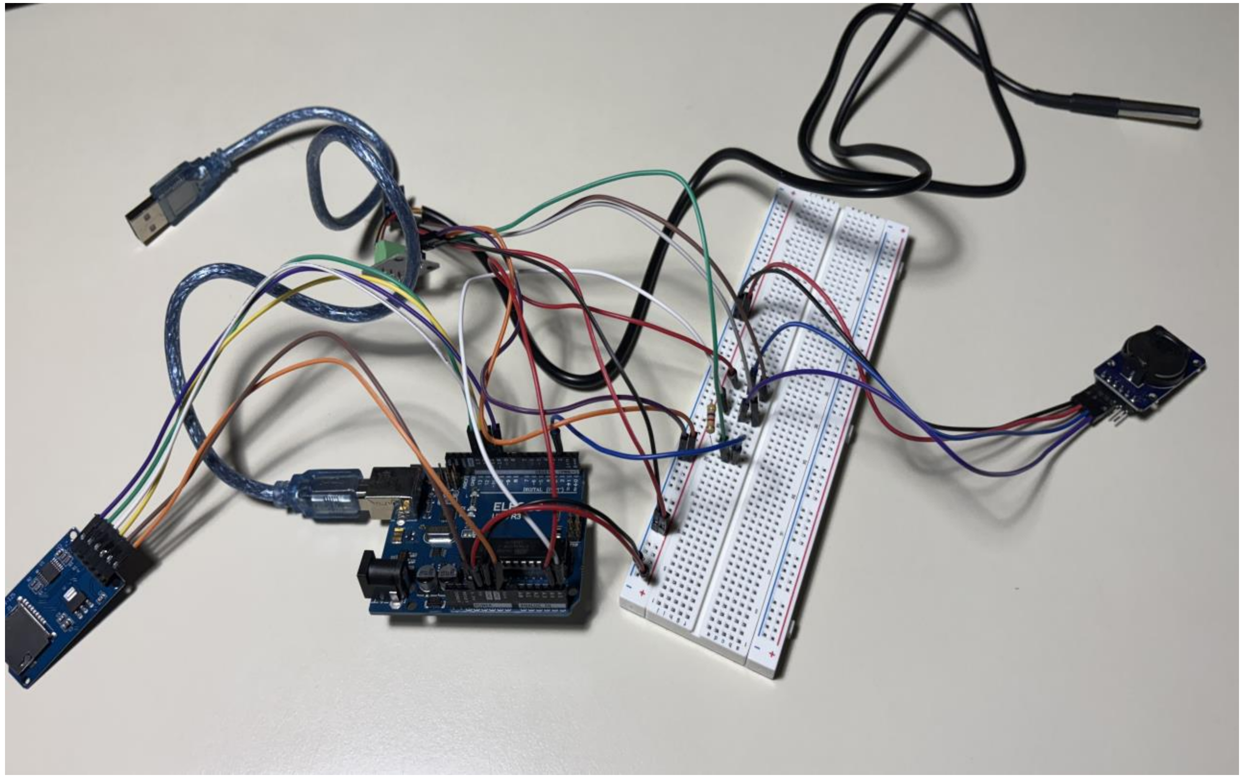
Demonstration

Figure 8: Apparatus View 1

Figure 9: Apparatus View 2

Figure 10: Apparatus View 3

Demonstration Data Collection

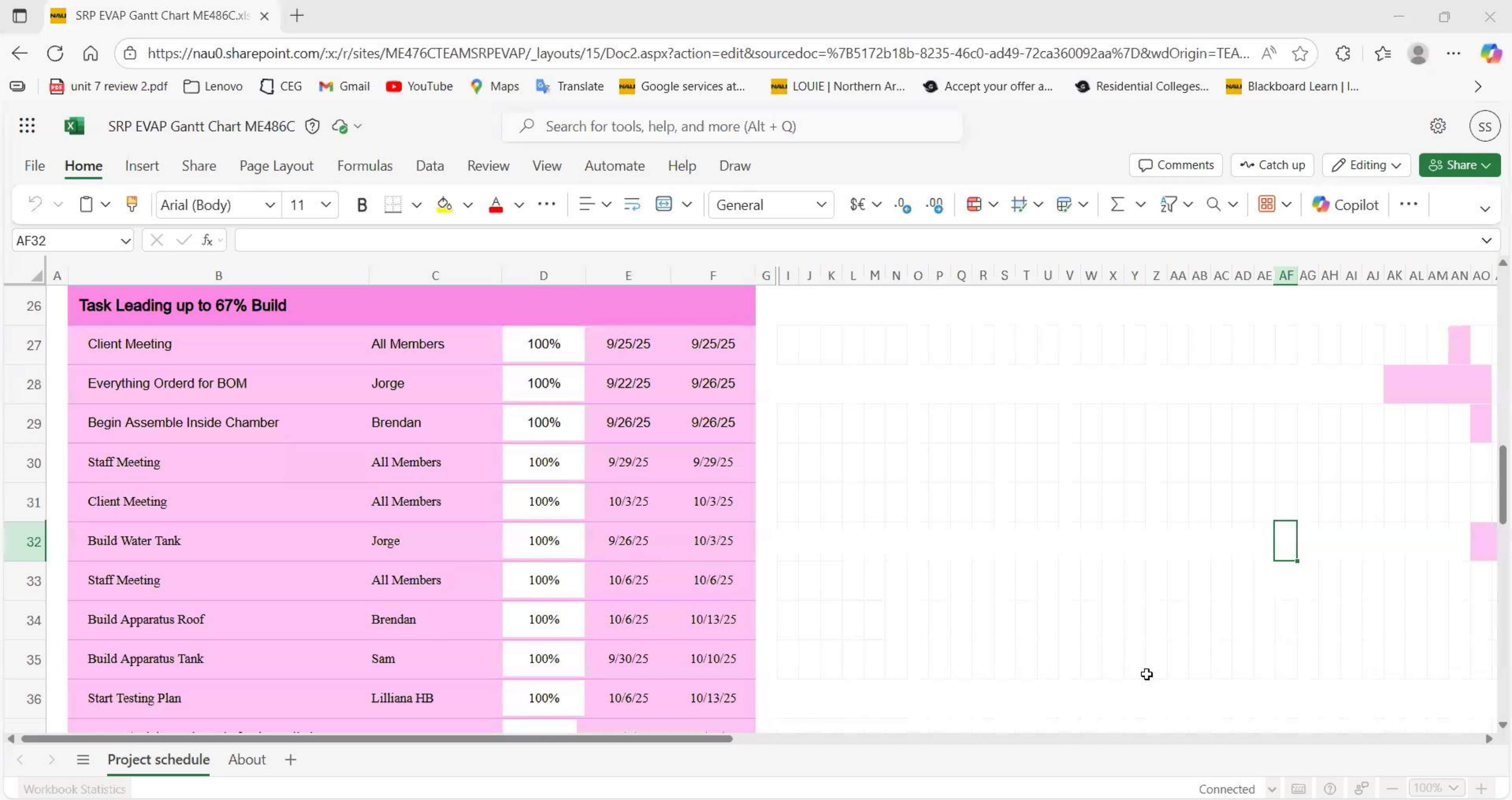


Timestamp	Air_Temp C	Humidity_%	Water_Temp C
2025-10-13 22:51:33	24.11	43.32	22
2025-10-13 22:51:38	24.09	43.03	22.01
2025-10-13 22:51:43	24.08	42.81	22
2025-10-13 22:51:48	24.06	43.18	22
2025-10-13 22:51:53	24.08	44.4	21.98
2025-10-13 22:51:58	24.08	44.57	21.99
2025-10-13 22:52:03	24.08	44.87	22.01
2025-10-13 22:52:08	24.06	44.87	21.99
2025-10-13 22:52:13	24.05	45.06	22
2025-10-13 22:52:18	24.09	45.18	22
2025-10-13 22:52:23	24.08	45.29	21.99
2025-10-13 22:52:28	24.09	45.36	22
2025-10-13 22:52:33	24.1	45.38	22
2025-10-13 22:52:38	24.08	45.37	22.01
2025-10-13 22:52:43	24.09	45.5	22.01

Gantt Chart

- Link to Gantt Chart

  SRP EVAP Gantt Chart ME486C.xlsx



	B	C	D	E	F
26	Task Leading up to 67% Build				
27	Client Meeting	All Members	100%	9/25/25	9/25/25
28	Everything Orderd for BOM	Jorge	100%	9/22/25	9/26/25
29	Begin Assemble Inside Chamber	Brendan	100%	9/26/25	9/26/25
30	Staff Meeting	All Members	100%	9/29/25	9/29/25
31	Client Meeting	All Members	100%	10/3/25	10/3/25
32	Build Water Tank	Jorge	100%	9/26/25	10/3/25
33	Staff Meeting	All Members	100%	10/6/25	10/6/25
34	Build Apparatus Roof	Brendan	100%	10/6/25	10/13/25
35	Build Apparatus Tank	Sam	100%	9/30/25	10/10/25
36	Start Testing Plan	Lilliana HB	100%	10/6/25	10/13/25

Moving Forward

- Finish Siphon
- Finalize Testing Plan
- Attach dehumidifier and sensors
- Start making excel sheet with built equations to process data
- Expand on evaporation modelling to verify results

Thank You!

NAU NORTHERN ARIZONA UNIVERSITY