Atmospheric Water Extraction Device

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Overview

Introduction

- Only ~2.5% of the water on Earth is freshwater, with 1% being easily accessible (Clean Water Crisis)
- There is a relatively untapped water source in atmospheric vapor
- Mr. Chris Allender, a NAU Biological Sciences graduate student, wants a device to study atmospheric vapor extraction

Need Statement

There is not enough research to determine if extracting water from air is a viable option in arid environments.

Project Goal

Create an atmospheric vapor extraction device to collect 2 liters of water per day and researching optimal operating conditions.

Objectives / Constraints

- Collect Water
- Portable
- Inexpensive
- Efficient Power Usage
- Run Continuously

- Data Logging
- Production Cost < $1000
- Residential Power Source (120V)

Concept Generation

Three ways of condensing water:

- Cooling the air
- Increasing pressure of the air
- Using brine solution

Cooling was decided to be the most efficient in terms of mechanical work and practicality.

Concept Selection

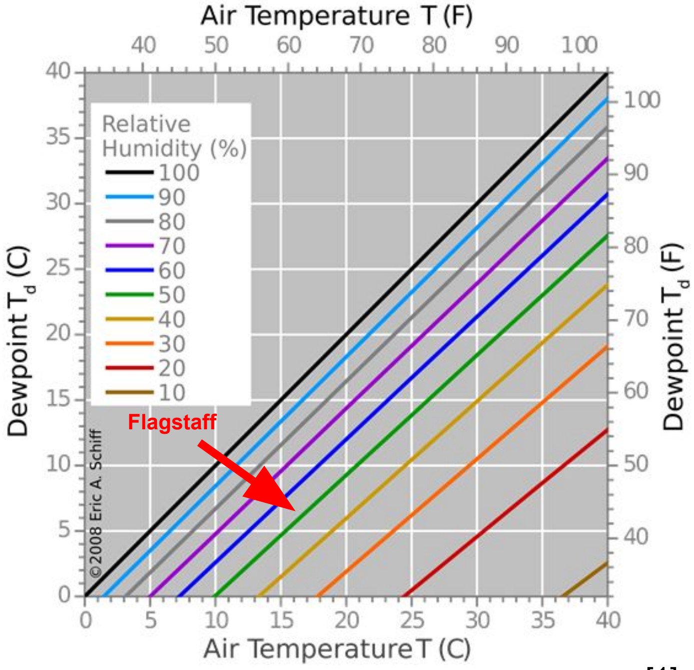
Two ways of cooling the air were considered:

- Passing air over refrigerated coils
- Passing air through a refrigerator with a heat exchanger

The refrigerator was chosen because it would double as a container to store the collected water.

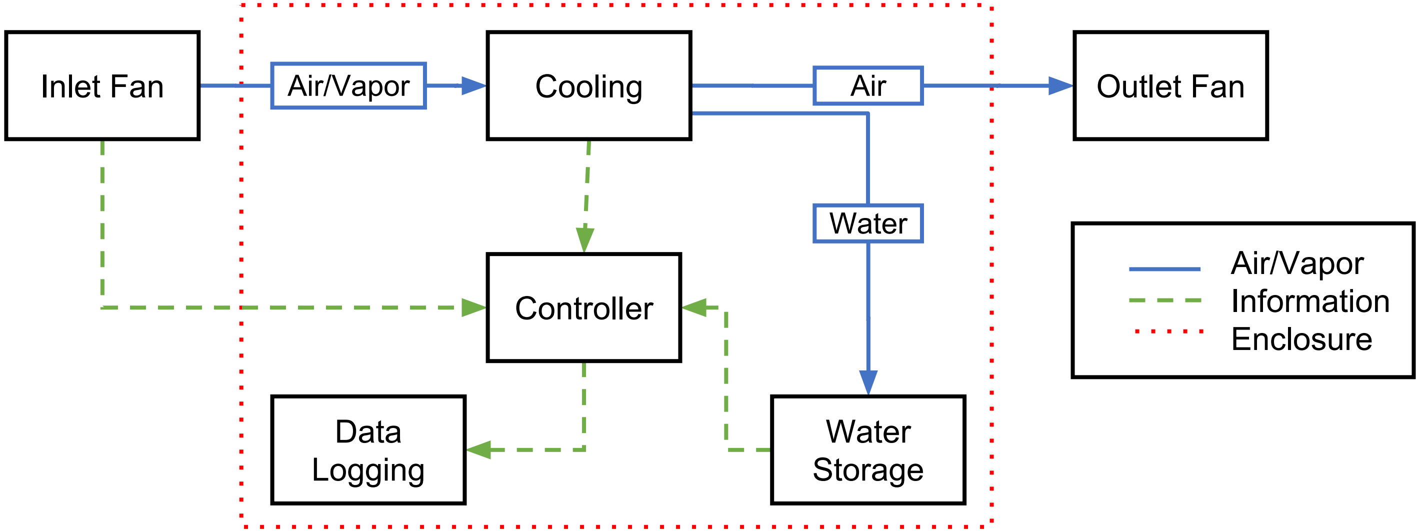
Cooling Calculations

- Used the *Magnus Formula* to estimate the Dew Point Temperature of Ambient Air
- Average Annual Temp of Flagstaff of 16ºC (61ºF)
- Average Annual Relative Humidity of 53%
- Dew Point Temp 6.43ºC (43.6ºF)
- Requires Avg. Temp. drop of ca. 10ºC (17ºF)
- Below 40% RH becomes increasingly difficult to extract water by cooling alone

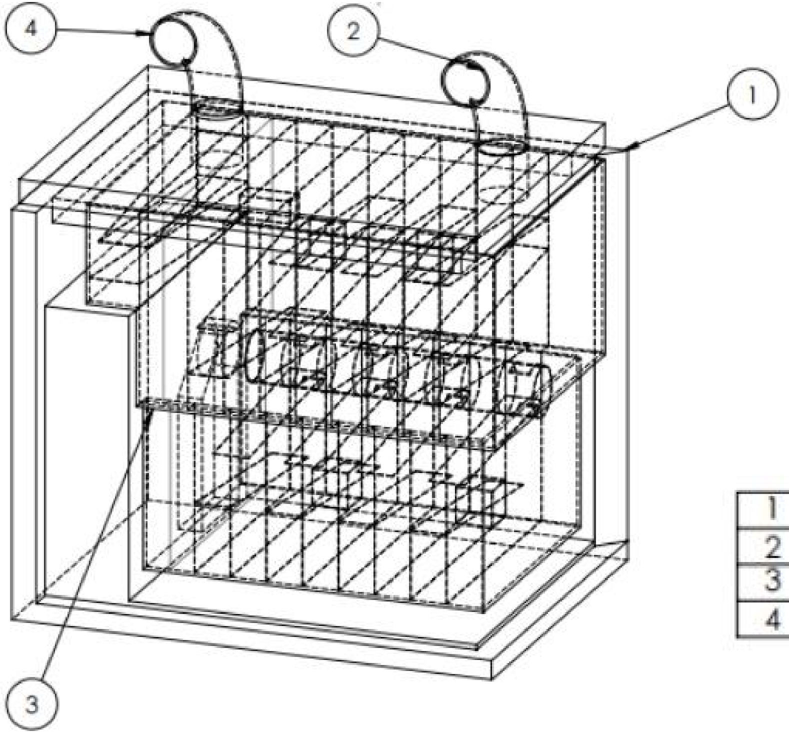


[1]

Functional Diagram



Final Design



1	Refrigerator
2	Fan(outlet)
3	Heat Exchanger
4	Fan(inlet)

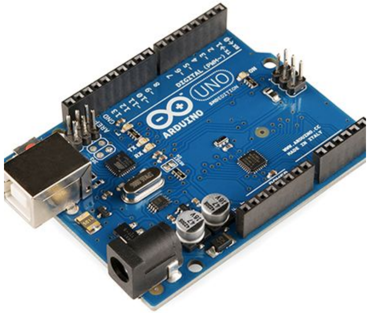
Cooling System

- Koolatron 52-Quart Krusader Cooler
- Cools up to 22ºC (40°F) below outside temperature
- 17.4 pounds
- 20 x 15.5 x 20 inches
- 12V power module with 120V AC adapter

Humidity Sensing

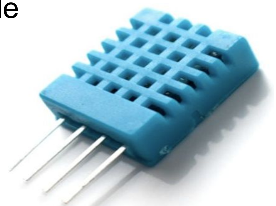
- The arduino is used to control the electronics

- The components include:
    - SD Card Module
    - DHT11 Humidity / Temp Sensor
    - Fans
    - Liquid Level Sensor
    - Water Pump
    - RTC (Real Time Clock)



Arduino Controller

SD Card Module


Humidity Sensor

Fan

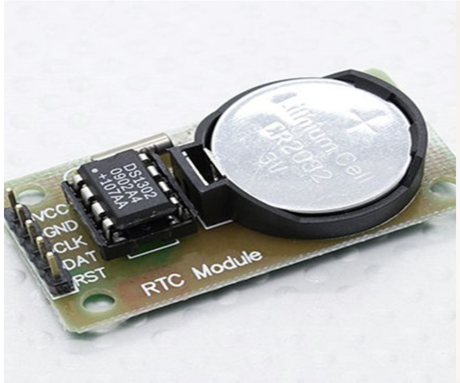
- Two 12v DC 4 pin fans
- First fan pushes air through inlet
- Second fan pulls air through outlet
- Speed is determined by the inlet humidity
- Rated airflow of 57.67 CFM

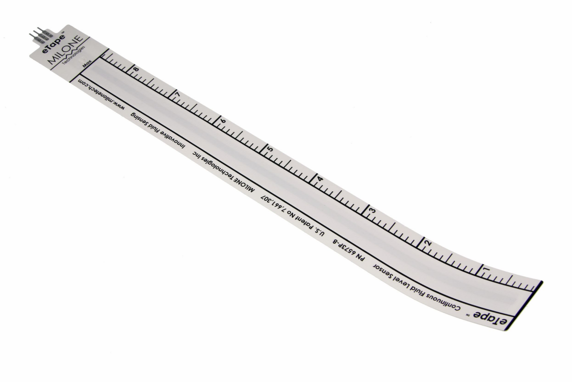
Water Measurement

- Real time clock (RTC) tells time so water can be measured and pumped out once a day

- Pump can run two ways to pump water in and out of tube

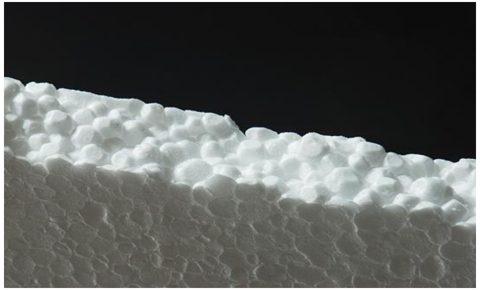
- Water measurement
    - Liquid level sensor in a tube of known volume
    - Controls when the pump reverses
    - Determines volume collected from number of cycles

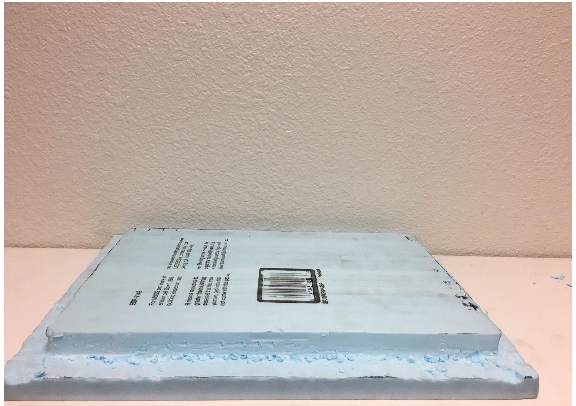




Lid and Housing

Lid is made of Polystyrene (R5) and cut with (vertical band saw)





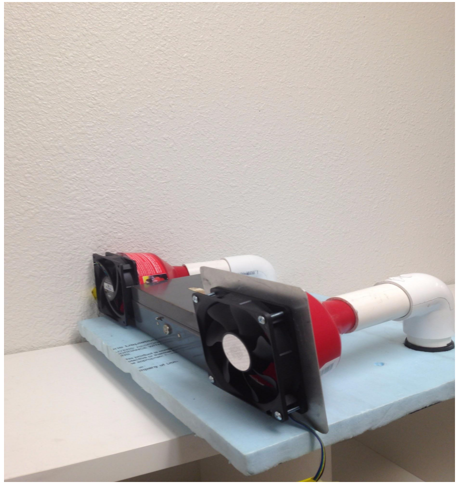
R5 Polystyrene Foam Board

Box cutter

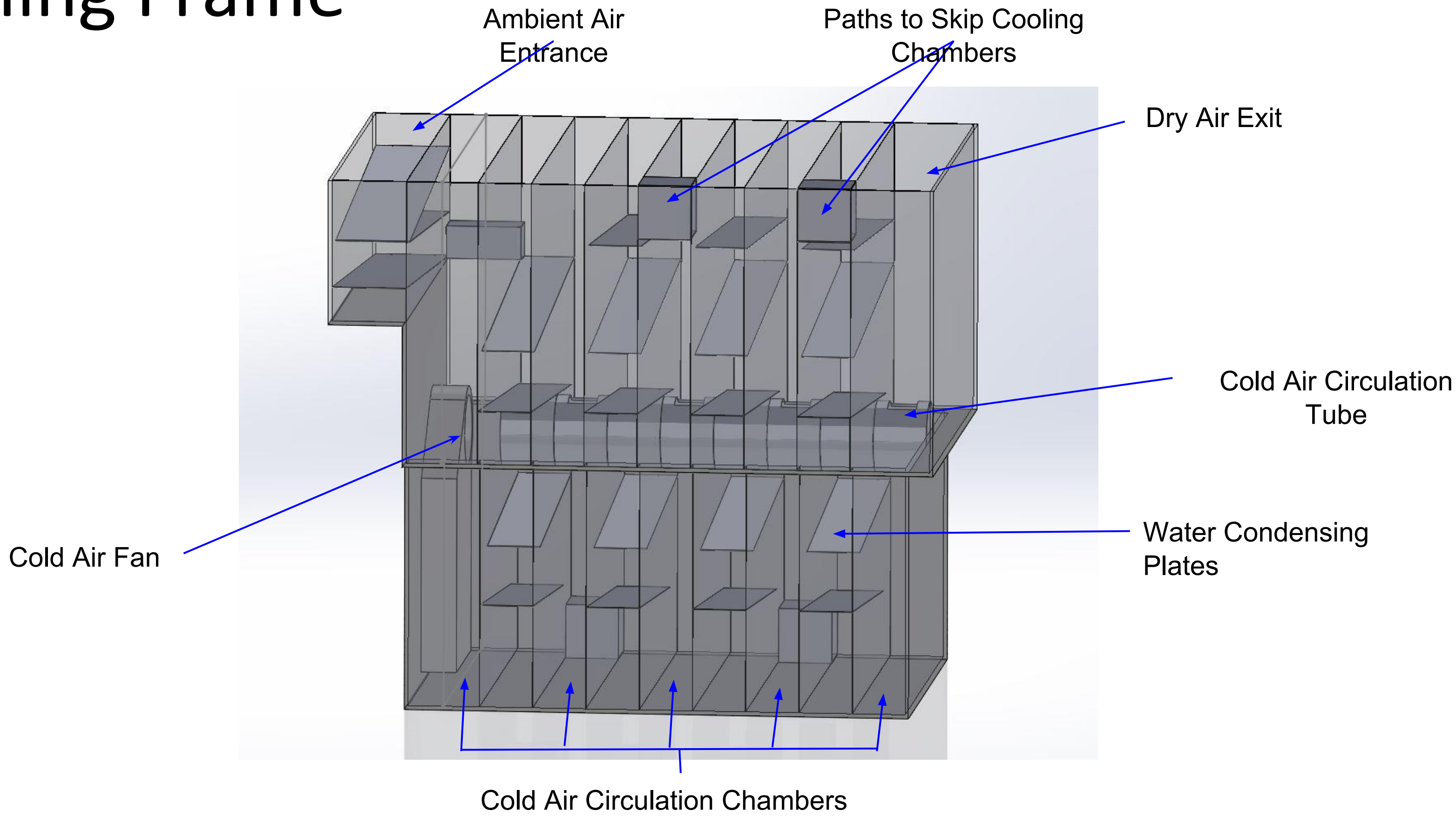
Lid and Housing - cont.

- Handles are screwed into the lid for reduced wear
- Holes drilled for inlet/outlet
- Funnel to concentrate the airflow
- Pipes to direct the inlet and outlet airflow
- Sensors placed in the pipes
- Housing for electronics

Lid Assembly



Cooling Frame



Frame

- Made of Aluminum for high thermal conductivity while resistant to corrosion

- The vertical plates, inserts, and pump housing were cut with tin snips and electric metal shears

- Stainless steel tube through center had holes milled in it

- Square inserts were cut to size with a vertical band saw

Performance Testing

The device was tested in multiple different operating conditions

- Ambient air conditions in typical Flagstaff home
  35% humidity (70°F)

- 65% humidity (70°F)

- Intake fan on, Exhaust fan off

- Both fans running

Noticeable condensation was found inside of the first two channels.

Water Condensing on Cooling Chambers

Results

Humidity (RH%)	Temp. (ºF)	Fan(s) Running	Time (hr)	Water (mL)
65	70	Both	24	300
35	70	Both	24	80
65	70	Inlet	24	250
35	70	Inlet	24	30

Future Modifications

- Increase ambient airflow
- Seal channels to walls
- Seal channel bypass connections
- Add more plates for condensation
- Increase angle of condensation plates
- Scale up to larger cooler (freezer)

Bill of Materials

Parts	Price
Portable Cooler	$169.00
Metal and Tools	$105.00
Lid Assembly	$88.00
Electronics	$193.49
Total	$555.49

Conclusions

- The team designed and created an atmospheric water extraction device for Mr. Chris Allender
- This design is easily carried by one person
- The device cools ambient air to its dew point temperature to condense water
- An arduino controller regulates fans and logs data from sensors
- Succeeded in collecting water from the atmosphere
- With RH ~65%, rate of 250 mL or more per day
- Could be scaled up to reach the 2 L per day goal
- Under budget at $555.49 out of $1000

Acknowledgements

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All the Machine Shop Employees

References

[1] E. Schiff (2008, Jan 4). *Dewpoint-RH mk.svg* [Online]. Available: http://www.wikipedia.com

[2] "SD Card Reader Module." *Geeetech.com*. N.p., n.d. Web.

[3] "Arduino." *Wikipedia*. Wikimedia Foundation, 06 Mar. 2016. Web. 05 Mar. 2016.

[4] "Kingduino Compatible DS1302 Real Time Clock Module with Battery."*HobbyKing Store*. N.p., n.d. Web. 07 Mar. 2016.

[5] "DHT11." *Amazon.com*. N.p., n.d. Web. 05 Mar. 2016.

[6] "Cooler Master Blade Master." *Amazon.com*. N.p., n.d. Web. 05 Mar. 2016.

[7] "ZJchao Peristaltic Liquid Pump." *Amazon.com*. N.p., n.d. Web. 06 Mar. 2016.

[8] "ETape Standard Liquid Level Sensor, 12-inch." *Parallax.com*. N.p., n.d. Web. 07 Mar. 2016.

Questions?