Atmospheric Vapor Extraction Device

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Concept Generation and Design

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1. Introduction

This report details the team's concept generation and selection. The team used multiple decision-making tools to aid in design choices. First, the functional diagram mapped out the overall design and its functions. Next, the team created criteria to begin a ranking process. This ranking process, analytical hierarchy process, gave numerical importance to the criteria. Finally, the decision matrices guided component selection.

2. Functional Diagram

To develop the functional diagram (Figure 1), the team considered extracting water by cooling the air to its dew point and collecting the condensation. This process will separate the vapor from the air and convert it to liquid water for storage. Sensors will collect data on the atmospheric conditions as well as the amount of water collected in the storage tank, then a data logging system will record it. These components will be placed in an enclosure that is small enough for one person to maneuver.

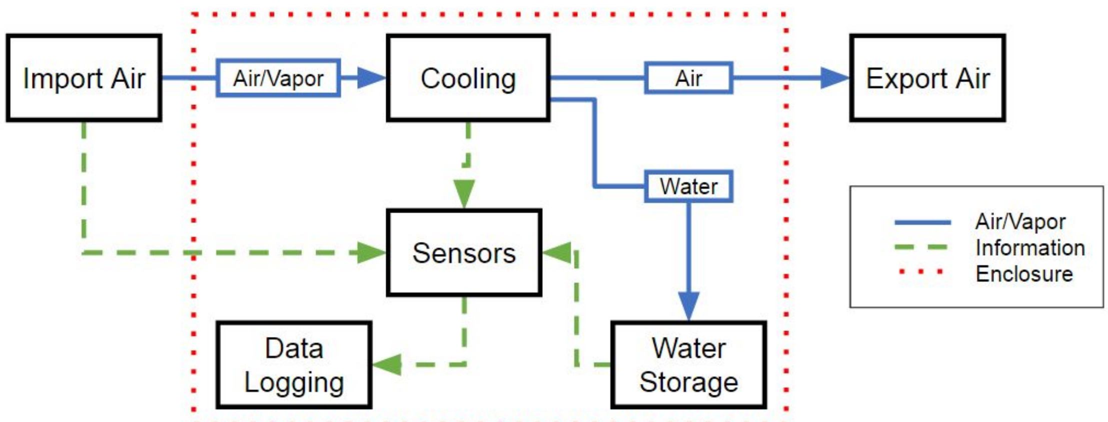

Figure 1 - Functional Diagram

3. Criteria

The following criteria were selected based on input from the client:

- **Size & Weight -** Size and weight were considered as criteria due to the constraint of having a portable device

- **Coefficient of Performance (COP)-** The Coefficient of Performance is important in order maximize the efficiency of the refrigeration cycle. Since most of the electrical energy is expected to be consumed by the refrigerator, the team wants a refrigeration cycle with a high Coefficient of Performance.
- **Accuracy -** According to the client, the device should collect data, so the team considered accuracy as the criterion to drive the data logging.
- **Initial Cost -** The team decided that the initial cost was important based on the $1,000 budget.
- **Running Cost -** Running cost was considered based on the client's need for the device to run overnight.
- **Ease of Use -** Ease of Use was considered in order to minimize interaction with the device.
- **Reliability -** The team decide to make reliability a criterion for the refrigerator and the sensors/datalogger to guarantee consistent performance.

4. Analytical Hierarchy Process

The Analytical Hierarchy Process was used to weigh the criteria numerically. This process uses a judgment scale (Appendix A) based on preference to score and weight the criteria. The values are then normalized to determine the relative weight of each. Appendix B gives an example of this process and the resulting relative weights for each component are shown below in Table 1**.**

Table 1 - Criteria Relative Weights

Function	**Power Source**					
Criteria	**Size**	**Weight**	**Initial Cost**	**Running Cost**	**Reliability**	**Ease of Use**
Relative Weight	12%	16%	27%	12%	21%	12%
Function	**Sensors / Logger**					
Criteria	**Cost**	**Reliability**		**Accuracy**		**Ease of Use**
Relative Weight	13%	29%		52%		6%
Function	**Refrigeration**					
Criteria	**Cost**		**Weight**		**COP**	
Relative Weight	33%		17%		50%	

5. Concept Generation

The team identified three main functions of the device. First, it needs to have a power source; second, it needs to have a condensing process; and lastly, it must have sensing equipment to detect and log the ambient weather conditions.

For power, the team considered the following options: outlet, generator, wind, and solar power. While sustainable power such as wind and solar is important, the reliability to run continuously will be taken into account. The condensing process cools the air by dissipating the heat. Many refrigeration devices are available on the market to do this. Other ideas included a thermoelectric heating elements or the use of dry ice. The former being vastly inefficient for cooling the continuous flow of air, with the latter needing to be constantly restocked. As a result, research was focused on a refrigeration cycle. The final function is the sensing and data-logging component. The team considered an Arduino-based, a Raspberry pi-based, and an all-in-one based system. The Arduino and Raspberry pi rely on small, programmable CPU’s that have the option of attaching sensors. The all-in-one option is available to buy and is specifically designed to sense and store weather data.

6. Decision Matrices

The decision matrix process, as recorded in Appendix C, ranked the following component options as the best:

- Power Source - Outlet
- Refrigeration - RCA Igloo RFR115-160 refrigeration unit
- Sensors/Data Logging - Arduino DHT11

Typical city power via a power outlet was found to be the best option for power source based on its high reliability and low initial cost. The Analytical Hierarchy Process has shown that these are the most important criteria to consider for power source. Additionally, it is easily accessible and limits the size and weight of the device. The RCA Igloo RFR115-160 was found to be the best for this project based on its high Coefficient of Performance and low cost. For the electronics, all three options scored well, however, the Arduino was chosen to be the preferred program used for data logging due to the team’s familiarity with the program.

7. Progression Plan

As shown in the updated progression plan (Figure 2), 19 activities were completed by the 7th week. The plan comprises both parallel and sequential activities. The project started on September 1st and was scheduled to end on December 7th. The schedule was divided into time spans of one week per sequential or a set of parallel activities. However, this chart does not present dependency of the activities.

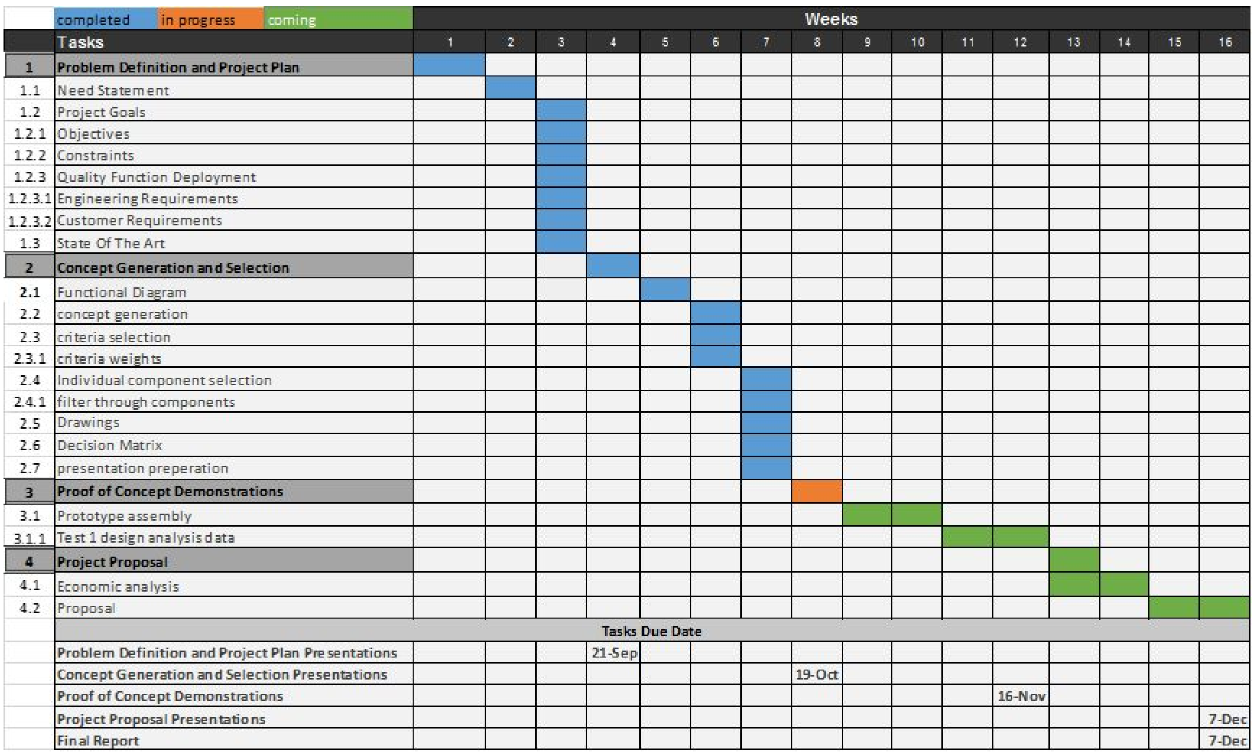

Figure 2 - Gantt Chart

8. Conclusion

The team relied on the above methodologies to choose a final design; namely, identifying the core functions of the design, developing criteria that aid those functions, and weighting those criteria to score and rank the concepts. Ultimately, the RCA 1.7 refrigeration unit was chosen based on its high ranking. It is expected to pump the heat out of the air to cool the vapor to its dew point so that water can be collected. Power will be provided by a 110v power outlet. The sensing and logging will rely on an Arduino based DHT11 sensor. Next, the team will obtain the condenser and move into prototyping to show that this functional model is feasible. When the first prototype is done, the functional model can be revisited to find improvements. One such improvement could be to compress the air to raise the dew point of the vapor.

9. References

[1] News, A. Achrnews. "The Basic Refrigeration Cycle." *Achrnews*. A, 30 June 2003. Web. 09 Oct. 2015.

[2] Boelman, E.C., B.B. Saha, and Takao Kashiwagi. “Experimental Investigation of a Silica Gel-Water Adsorption Refrigeration Cycle -- The Influence of Operating Conditions on Cooling Output and COP.” United States: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA (United States), 1995. Print.

[3] "Electric thermometer by using DHT11 sensor module." *Geeetech*. N.p., n.d. Web. 23 Oct. 2015.

APPENDIX A - Scales

Table A1 - Judgement of Preference

Judgement of Preference	
Judgement of Preference	**Numerical Rating**
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1

Table A2 - Refrigeration Scale

Refrigeration Scale				
Performance Level	**Value**	**Cost ($)**	**Running Cost (W)**	**Weight (lbs)**
Perfect	10	0	0	0
Excellent	9	100	100	10
Very Good	8	200	200	20
Good	7	300	300	30
Satisfactory	6	400	400	40
Adequate	5	500	500	50
Tolerable	4	600	600	60
Poor	3	700	700	70
Very Poor	2	800	800	80
Inadequate	1	900	900	90
Useless	0	1000	1000	100

APPENDIX A - Scales

Table A3 - Power & Data Logging Scale

Power & Data Logging Scale	
Performance Level	**Value**
Perfect	10
Excellent	9
Very Good	8
Good	7
Satisfactory	6
Adequate	5
Tolerable	4
Poor	3
Very Poor	2
Inadequate	1
Useless	0

APPENDIX B - Analytical Hierarchy Process Example

Table B1 - Power Source Criteria Weights

Power Source						
	Size	**Weight**	**Initial Cost**	**Running Cost**	**Reliability**	**Ease of Use**
Size	1	1/3	1/5	1/5	1/7	5
Weight	3	1	1/5	1/5	1/7	3
Initial Cost	5	5	1	3	3	5
Running Cost	5	5	1/3	1	1/3	3
Reliability	7	7	1/3	3	1	3
Ease of Use	1/5	1/3	1/5	1/3	1/3	1

Table B1 - Power Source Criteria Relative Weights

Power Source							
	Size	**Weight**	**Initial Cost**	**Running Cost**	**Reliability**	**Ease of Use**	**Rel. Weight**
Size	0.047	0.018	0.088	0.026	0.029	0.250	**8%**
Weight	0.142	0.054	0.088	0.026	0.029	0.150	**8%**
Initial Cost	0.236	0.268	0.441	0.388	0.606	0.250	**35%**
Running Cost	0.236	0.268	0.147	0.129	0.067	0.150	**17%**
Reliability	0.330	0.375	0.147	0.388	0.202	0.150	**27%**
Ease of Use	0.009	0.018	0.088	0.043	0.067	0.050	**5%**

APPENDIX C - Decision Matrices

Table C1 - Power Source Decision Matrix

Power Source					
	Wind	**Solar Panels**	**Generator**	**Outlet**	**Battery**
Size	0.33	0.57	0.51	1.02	0.87
Weight	0.48	0.68	0.40	1.28	0.92
Initial cost	1.15	1.15	1.15	2.16	1.49
Running cost	0.78	0.90	0.39	0.69	0.72
Reliability	0.84	1.16	1.26	1.42	1.05
Ease of use	0.39	0.57	0.63	0.96	0.90
Total	3.97	5.02	4.34	7.53	5.95

Table C2 - Refrigeration Decision Matrix

Refrigeration			
	True 884621 1/6 HP - 115V	**RCA**	**Frigidaire**
Cost	1.77	2.93	2.71
Weight	1.16	1.11	0.87
Coefficient of Performance	4.38	4.65	1.28
Total	7.30	8.70	4.85

Table C3 - Data Logging Decision Matrix

Data Logging			
	Arduino Based	**Raspberry Pi Based**	**All-in-One**
Cost	0.91	0.78	0.65
Reliability	2.03	1.45	1.74
Accuracy	3.64	3.64	4.16
Ease of Use	0.54	0.24	0.24
Total	7.12	6.11	6.79