Active Roof System

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Team 06

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Document

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1.0 Brief Project Description

The amount of power needed to maintain a constant comfortable temperature inside of large warehouse like buildings is too high. In order to investigate possible solutions to this problem, our team will design and build prototypes of active and passive roof systems that are designed to reduce the amount of energy required to maintain a cool, comfortable temperature.

2.0 Forming a Hypothesis

In order to be able to check the validity of the measured data that will be collected during testing, a hypothesis on the behavior of the system must be formed. The hypothesis for this project will consist of an estimation of the energy consumption required in order to keep the inside of the prototypes at approximately 70^{o}F. For a simplified model of the heat being transferred in or out of our system (Aka the prototype), see Figure 1 below:

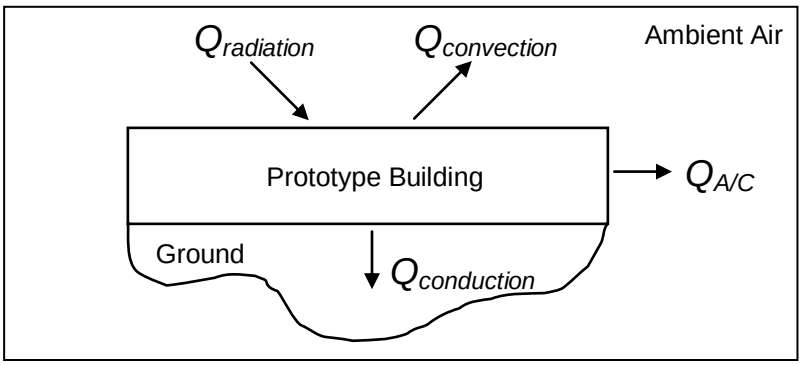

Figure 1: Diagram of Heat being Transferred In and Out of the Prototypes

The directions of the arrows are only a guess based on the testing set up; however, the direction itself does not matter because it does not actually change the absolute value of the resulting Q_{energy}.

In order to produce this simplified model of our experiment and to calculate reasonable predictions from it, our team is working closely with our client Dr.Shafer. This simplified model will be used to create a program which will be able to calculate Q_{energy} based on different given inputs, and then these Q_{energy} values will be compared to the experimental data collected by the prototypes.

3.0 Testing Methods

After consulting with our client, Dr.Shafer, about what he would like to see from the results of the experiments completed on the prototypes, our team has decided to change the testing environment as well as the method of testing the roof systems.

The testing environment will now consist of a controlled room with a simulated sun. The controlled environment will be indoor room with no fans or windows that is on the first level of a building, and the prototype will be set on the floor of this room. It is essential that the prototype be set on the floor of the first level of a building, because then it will simulate the ground by acting as large thermal reservoir.

A heat lamp, like those used in reptilian habitats, will be used as the simulated sun. The heat lamp selected shall be one that not only emits heat but also UV radiation, so that it is a closer imitation to natural sunlight. The heat lamp itself will be hung upon a handmade arc, made of piping or lightweight metal tubing, so that it may be suspended above the prototype during testing.

This will work as an excellent testing environment because then all test trials can be easily compared to each other no matter what day or time of day the testing occurred, because every test will have the same influencing factors such as ambient temperature, ground temperature, and amount of radiation the prototypes are exposed to. If the prototypes were tested outdoors like each day, and that would make the collected data harder to analyze.

The testing method itself also changed from the testing taking a full day of sunlight (approximately 8 hours) to the entire testing procedure being expedited so that it will only take two hours to complete. During those two hours, the heat lamp will be moved into a new position on the arc every five minutes to simulate the sun moving into different positions across the sky. The already collected sunrise and sunset angles for Flagstaff, AZ will be used to approximate the start and the end positions of the heat lamp. In addition, the program that will control the rotation of the active roof system's panels will also be modified, so that they automatically rotate the proper amount of degrees every five minutes to simulate solar tracking.

4.0 Ordering Materials

For the first round of gathering materials, our team has already ordered the main materials required to begin constructing the prototype building.

The main and most expensive materials needed to be ordered in bulk from an online source. These online ordered materials are shown in Table 1 on the following page:

Table 1: Materials Ordered Online

Material	Expected Delivery Date	Supplier	Price per Unit	Quantity Needed	Cost
Square Wooden Dowels	2/5/2014	HomeDepot	$3.50	54	$189.00
Light Cork Roll	1/29/2014	Hobby Lobby	$14.99	15	$249.06
Mylar	1/28/2014	Amazon	$29.95	1	$29.95

For a list of all materials that have been purchased in this first round of gathering materials, see Table 2 below:

Table 2: All Materials Currently Purchased

Material	Expected Delivery Date	Supplier	Price per Unit	Quantity Needed	Cost
Square Wooden Dowels	2/5/2014	HomeDepot	$3.50	54	$201.71
Poster Board	1/27/2014	Walmart	$0.99	24	$23.76
White Duct Tape	1/27/2014	HomeDepot	$4.99	1	$4.99
Light Cork Roll	1/29/2014	Hobby Lobby	$14.99	15	$249.06
Nails	1/27/2014	HomeDepot	$9.37	1	$9.37
Mylar	1/28/2014	Amazon	$29.95	1	$29.95
Foam Poster Board	1/27/2014	Walmart	$3.00	4	$12.00
				TOTAL:	**$530.84**

For these main materials, enough was ordered so that there would actually be enough to make two prototype buildings. This was done on purpose so that there will be extra material to use in case of mistakes or mishaps.

Some of the other materials that still need to be purchased include the materials needed to construct the A/C systems, the temperature monitoring systems and the active roof rotation system; however, these materials will not be bought once solid designs for these systems are established.

5.0 Construction Plan

Constructing and possibly testing of the prototypes will take place in NAU's building 98C (the Fabrication Shop). Our team has already reserved a work bench and a locking cabinet.

In order to lower the amount of supplies needed and the time of construction, our team has lowered to amount of prototype buildings to only one. The control, passive, and active roof systems will be interchangeable pieces which can be attached and detached from the one

prototype building. This change in design is expected to lower our estimated cost by approximately a half, and save a few weeks of construction time.

The first step of action will be to construct the only prototype building and the active roof system. The active roof system itself will be one of the most time consuming assembly to construct, and therefore it should be one of the things started first. The details on the construction of the active roof system are described in the following section (Section 6.0).

The other system which will take a large amount of time to construct and to get working properly is the A/C systems. The control/passive prototype building will be the first prototype to have the A/C unit installed and tested on since it is the most disposable and easy to rebuild in case of an error. A full description of the new A/C system is given in Section 7.0.

6.0 Active Roof Rotation System

The active roof prototype will have panels that are attached to a shaft. Each shaft will have a small sprocket attached to one end, then all of these sprockets will be set in parallel and a bike chain or similar will be used to connect all of them. A servomotor will also have a small sprocket attached to its shaft and then that sprocket will also be within the bike chain. This chain will allow the motor to rotate all panels at the same time and to the same angle. The motor will still be controlled by an Arduino board that will be programmed to tell the motor when and how much to rotate.

7.0 Planned A/C System

Over break, the design for the A/C system has changed drastically, from a forced air system to a radiant air cooling system. This was changed due to the design's ease of manufacturing, and the fact that a forced air A/C system for the size that is needed does not exist.

The new design will consist of coiled copper piping that will weave through the inside of the prototypes carrying cold water. The cold water will be pumped through the pipes using a simple pump, like those used in fish tanks, and the control system will consist of an Arduino board that will turn on and off the pump depending on the temperature readings that are gathered from the temperature measuring system.

With the new design, calculations will be required to determine the temperature of the water that will be flowing through the pipe, the volumetric flow rate of water that is necessary to cool the model and the sizing of the pipe to allow optimal flow without excessive pressure.

8.0 Spring Timeline

A new timeline was created to help in aiding our team to keep on track with the completion of tasks. It also gives helped us to understand which tasks can be worked on simultaneously, and that will cause us to work more efficiently. Our team's new Spring 2014 timeline is shown in Figure 2 below:

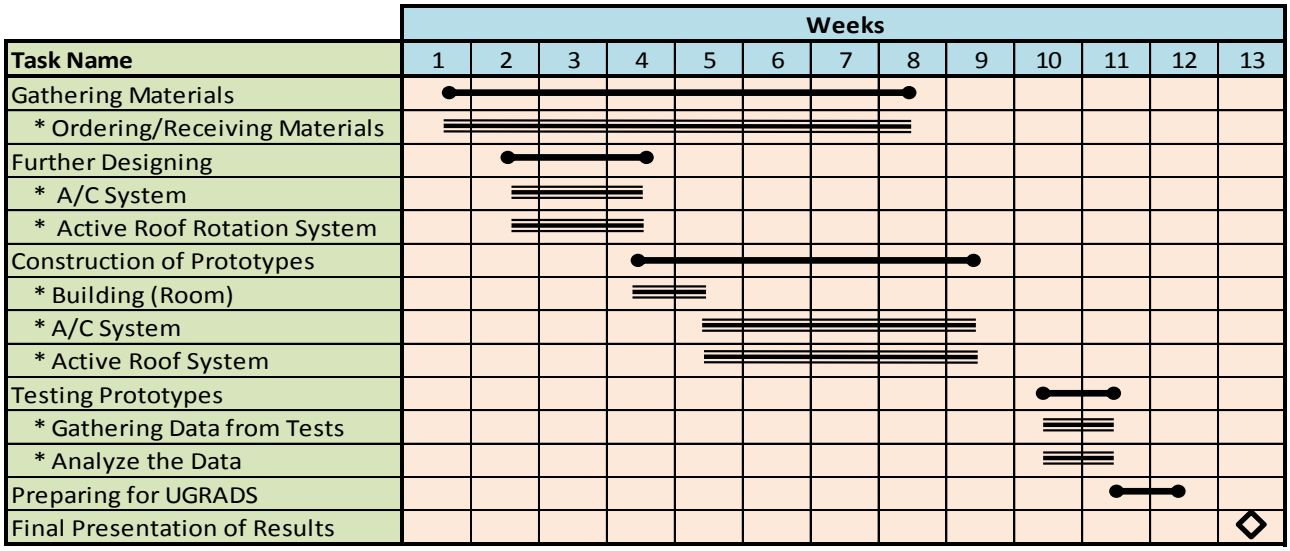

Figure 2: Spring 2014 Timeline

Currently, our team is right on schedule with this new timeline because we are in the 3rd week and some main materials have already been ordered and the A/C and active roof rotation system are being designed.

Our team is expecting to receive the first ordered set of materials this within the next two weeks and then construction of the prototypes may begin sometime next week. The construction phase of the prototypes should take at most six weeks to complete, and at the same time continuing to order more needed materials. Once the construction of the prototypes is completed, then testing of the prototypes can begin. Within the testing phase, data for each prototype will be collected and then these results will be compared to the hypothesis and the team's basic knowledge of heat transfer and thermodynamics to check for validity. If the test results do not reasonable then modifications will be made to the testing method or the prototypes and then retesting will occur. The last two weeks of the Spring 2014 semester will be used to finalize our project results and prepare for the UGRADS presentation.

9.0 Job Assignments

On order to work most efficiently on the construction of the prototypes, each team

member has been assigned specific projects. Table 3 below, shows the list of assigned projects:

Table 3: Team Job Assignments

Team Member	Job Assignment 1	Job Assignment 2
Mohammed Alkhaldi	Temperature Measurement System	Power Usage Programming (Audriuno Board)
Coy Cody	Construction of Prototype Building	Construction of Passive Roof
Donovan Hard	Construction of Prototype Building	A/C System Design & Construction
Marissa Munson	Active Roof Programming (Audriuno Board)	Construction of Active Roof Panels
Krysten Whearley	Active Roof Rotation Design & Construction	Forming a Hypothesis (Heat Transfer Analysis)

In Table 3 above, the title "Job Assignment 1" implies that the project is either that team member's main focus or that it must be started before "Job Assignment 2" due to construction priorities.

10.0 Conclusions

Currently, our team is forming equations to input into a program that will estimate the energy usage of the prototype's A/C system, and is designing the A/C and active roof rotation systems. The first set of ordered materials should be delivered within the next week, and then construction on the prototype building can begin. Our team's goal is to have the construction of the prototypes completed by the 9th week in the semester, so that gives us a rather generous building period of six weeks.

The testing of the prototypes will take place indoors in a controlled environment with a simulated sun. The testing process will only last for two hours, will make use of a heat lamp for the simulated sun, and that heat lamp will be move manually along a constructed arc every five minutes.

Only one prototype building will be built and then all the different roof systems (control, passive and active) will be interchangeable components which can be switched out during testing.

The A/C and active roof rotation systems will take the longest to construct and test, so they will be one of the first projects worked on. The A/C system will consist of ice water pumped through coiled copper pipes, and will be inserted into the inside of the prototype. The active roof rotation system will consist of a gear and chain system which rotates the panels using a motor.