Active Roof System

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Team 06

Problem Formulation and Project Plan
Document

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Mechanical Engineering Design I – Fall 2013

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Contents

1.0 Project Introduction

The amount of power needed to maintain a constant comfortable temperature inside large warehouse type buildings is too high. To amend this problem our group will design and build prototypes of active and passive roof systems designed to reduce the amount of energy required to maintain a desired temperature.

2.0 Clients

Project clients who will be sponsoring this project are as follows:

- Dr. Michael Shafer – Mechanical Engineer/Professor at Northern Arizona University
- Grant Masters – Graduate Student at Northern Arizona University

Although Dr. Shafer is the faculty member who is sponsoring this project, our main client and the one we will be in most contact with, as instructed by Dr. Shafer, is Grant Masters.

3.0 Need Statement

Every project has a basic need statement that can be used to guide the possible solutions to the problem at hand. For this project, the needs statement is as follows:

The amount of power usage to keep the interior of large buildings at a comfortable, cool temperature is too high.

4.0 Goal

The goal of this project is to design and build prototypes of active and passive roof systems that will maintain a closed interior structure at constant temperature while withstanding all the extreme weather conditions associated with of all four seasons.

5.0 Brief Description of Prototypes

For this project there will be three basic roof system prototypes constructed: a passive design, an active design, and a control that will be used for comparison purposes to calculate the efficiency of the other two.

The project goal is to design active and passive panel systems that will be placed on the roof of the building to decrease the need of energy to maintain the temperature of the building's interior. An active roof system unit consists of panels that will actively track the sun by use of a solar tracking device. During the summer months the panels will change angles throughout the day so that they will reflect the sun's radiation (or thermal energy) to keep the building's interior cooler (see Figure 1 below) [1]. By continuously changing the angles of the panels throughout the day it will also cause the maximum amount of the roof's surface are to be shaded, which will also help to decrease the amount of heat absorbed by the roof. Then during the winter months, these panels will do the exact opposite: they will change angles throughout the day to allow the sun's radiation to be absorbed by the black roof and help to heat the building's interior (see Figure 2 below) [1].

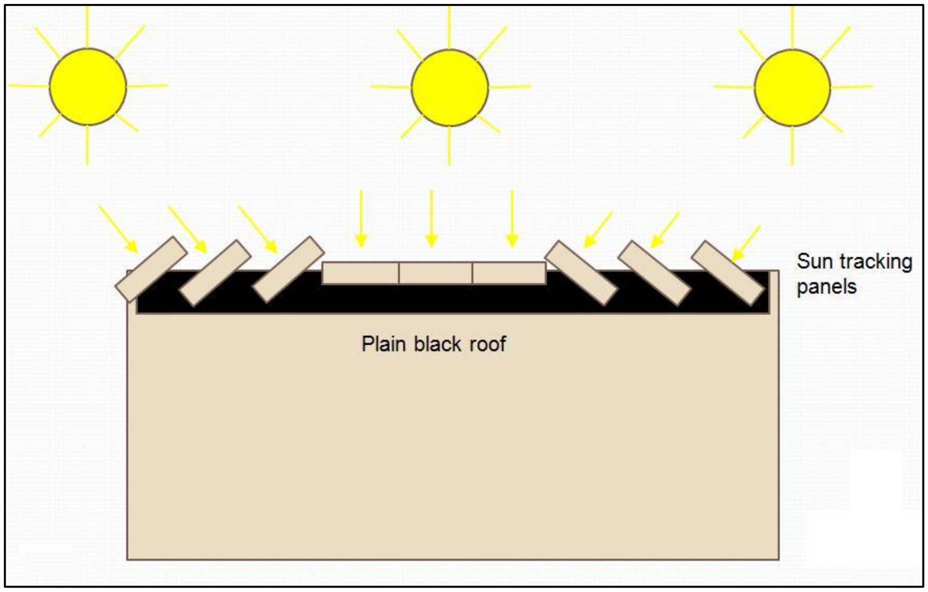

Figure 1: Active Roof System Panel Angle for Summer Months throughout a Day

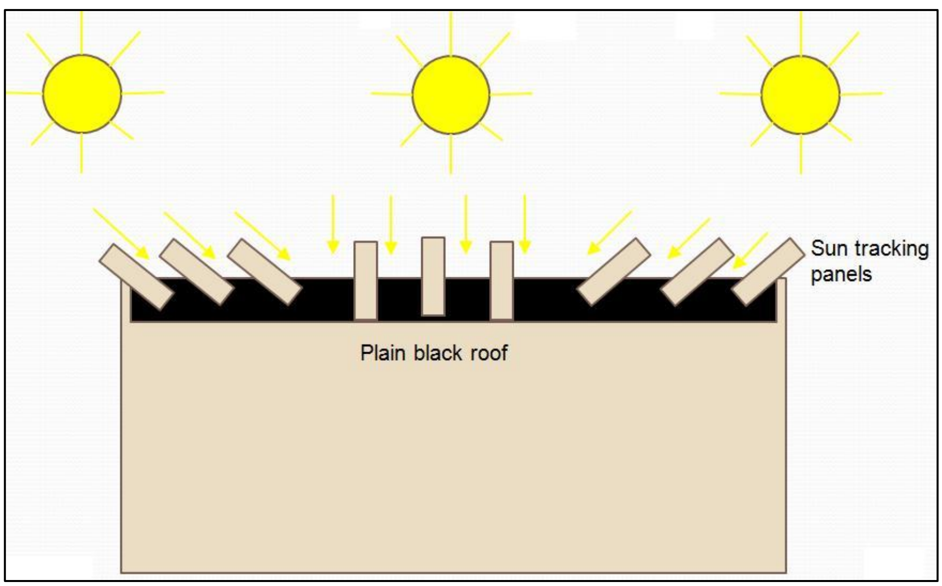

Figure 2: Active Roof System Panel Angle for Winter Months throughout a Day

The passive roof system will be very similar to the active roof system, in that they both will be blocking sun's radiation during the summer months, and then allowing the sun's radiation to be absorbed by the building's black roof during the winter months [1]. The main difference between the passive and active roof system, is that the passive roof system will not track the sun. Instead the passive roof's panels will be stationary and be placed at an optimal angle that will be the most efficient during that time of year at absorbing or reflecting the sun's radiation [1].

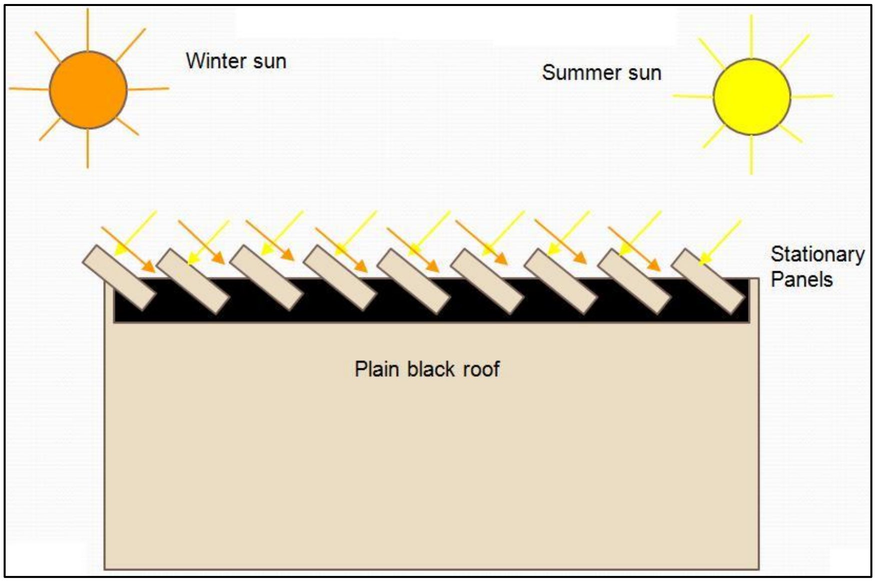

Figure 3: Passive Roof System Panel Angle for Winter and Summer Months

The control roof system will be modeled as a building with a flat, white painted roof to reflect as much of the energy as possible [1]. Many large building have white painted roofs, just for that purpose so having this as the control prototype is valid.

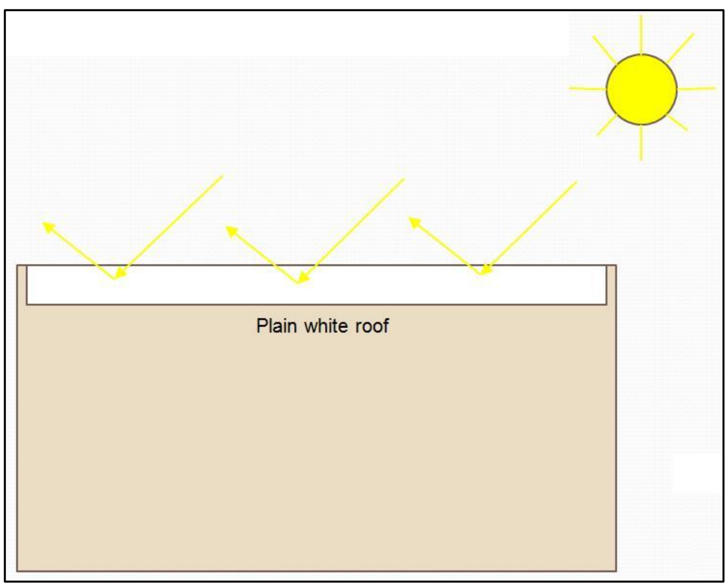

Figure 4: Control Roof System

6.0 Expected Project Outcome

The expected outcome for this project is to design and build improved and inexpensive active and passive roof prototypes that will help maintain interior structure temperature of 70 degrees Fahrenheit. Additionally, the system design will conserve power usage by using solar energy to provide the heat needed to maintain a desired constant temperature.

7.0 Operating Conditions

For this project there are two different operation conditions which will be used for the design and testing of the three prototypes.

The first operating condition will be in a computer lab and conducted mainly by the graduate student, Grant Masters. Mr. Masters will be doing the analytical computer simulations to show an estimate of the effectiveness of each prototype to either transfer heat away from or into the system. However, our team will be making simple heat transfer calculations and concepts to aid us in the selection of our final prototype designs.

The second operation condition comes in when it is finally time to test the prototypes. The prototypes will be tested outdoors where they will be exposed to a variety of weather conditions throughout an entire day. Measurements will also be taken throughout the testing days so that our team can analyze how effective each prototype is at maintaining the required constant internal temperature of 70 degrees Fahrenheit.

8.0 Objectives

The measurable objectives and how they will be measured for each prototype are shown in the table below:

Table 1: Project Objectives

Objective	Measurement Basis	Units
Maintain Constant Internal Temperature	Interior Temperature of Structure Throughout a Day	°F
Reflect/Absorb the Sun's Radiation	External Roof Temperature Throughout a Day	°F
Low Power Usage	Power Used by Control, Active and Passive Roof to Maintain Internal Temperature	kWh

9.0 Client Needs

Achieving client needs is absolutely necessary for the design phase of any product. The following are of the needs expressed by our two clients:

1. *Seasonal* - Customers need to have an active roof system that work in all seasons. The apparatus need to withstand at a high temperature and at a freezing temperature.
2. *Weight* - The light weight is essential for the apparatus so that it can be maintained easily. The lowest weight it could be, the lowest cost it would be.
3. *Cost* - The cost of the apparatus is important. The cost need to be as low as it could be so it will be affordable for most customers.
4. *Power Input* - The power input to rotate panels need to be low. The purpose of this design is to reduce energy usage.
5. *Stiff* - The apparatus need to be able to withstand harsh climate. The stiffest it could be, the more durable and life it will have and that what most customers are looking for.
7. *Ease to Control* - The apparatus will use a thermostat to control the system. If thermostat is complex, we will have less chance to make our design at the top of market.

10.0 Engineering Requirements

In order to come up with effective passive and active roof systems our team will need the following engineering tools and knowledge:

- How to conduct a heat transfer analysis
- Background knowledge of effective Solar Tracking Systems
- Knowledge of in Automated Systems in general.

Some of the engineering properties/requirements that will be needed for the design of the prototypes are listed below:

- Material Strength
- Efficiency
- Weight
- Manufacturability
- Durability
- Functional
- Accuracy

The client needs listed within the previous selection are analyzed for which of engineering requirements they correlate to in the Quality Function Deployment Figure 5 below:

Client Needs	Client Weights	Material Strength (YS)	Efficiency	Weight	Manufacturability	Durable	Functional	Accuracy	Active Design	Passive design
		Engineering Requirements							Benchmarks	
1. Seasonal	9	8	9			9	8	9	X	X
2. Light Weight	4	2		10		7	5			X
3. Low Cost	10	4	6	9	8	5	9	7		X
4. Minimum Power input	10		9					6		X
5. Stiff	6	10		8		6	6		X	X
6. Efficiency	8		10			4	9	8	X	
7. Easy to Control	7			6			6	3		X
	Unit of Measure	psi	KWH	lb	Unitless	Unitless	Unitless	θ		
		Technical Target								

Figure 5: QFD Table for Project

The yellow columns in the QFD above show how much each engineering requirement correlates to each of the client needs on a scale of 1 to 10. If there is no value represented, then that means that there is no correlation between that particular engineering requirement and client need. The gray columns show which of the client needs are expected to be fully fulfilled by each type of roof system.

It can be seen from this table that the customer needs which are of top priority are to produce low cost of construction prototypes' that use a minimal amount of power to operate. The fact that these two needs hold the most importance to the client makes sense because if the prototype is inexpensive to construct then that will correlate to the full scale models also being relatively inexpensive to manufacture, and of course the prototype has to use a minimal amount of power because the point of these roof systems is to reduce the amount of power used to cool/heat the interior of buildings, so it would be pointless if the roof systems used the same amount of power as the building would normally without it.

11.0 Constraints

The three constraints that are known for this project so far are listed below:

- The interior of the prototype must be able to maintain a constant temperature of 70 degrees Fahrenheit throughout the entire day of all four seasons.
- The prototypes must be able to withstand various extreme weather conditions such as blizzards, ice storms, hail, lightning, dust storms, gusty winds, and extreme dry climates.

- The cost of the construction of the prototypes must be below the (future, client) assigned budget.

These constraints come directly from the initial list of client needs listed in the previous section, and will be added to as more information is gained.

12.0 Project Planning

A basic timeline was made to help us keep on track with the completion of tasks and reminding us the due date of each task. It also gives us an idea of what tasks may be worked on simultaneous so that we are able to work more efficiently.

The Fall 2013 Timeline is shown in Figure 6 below:

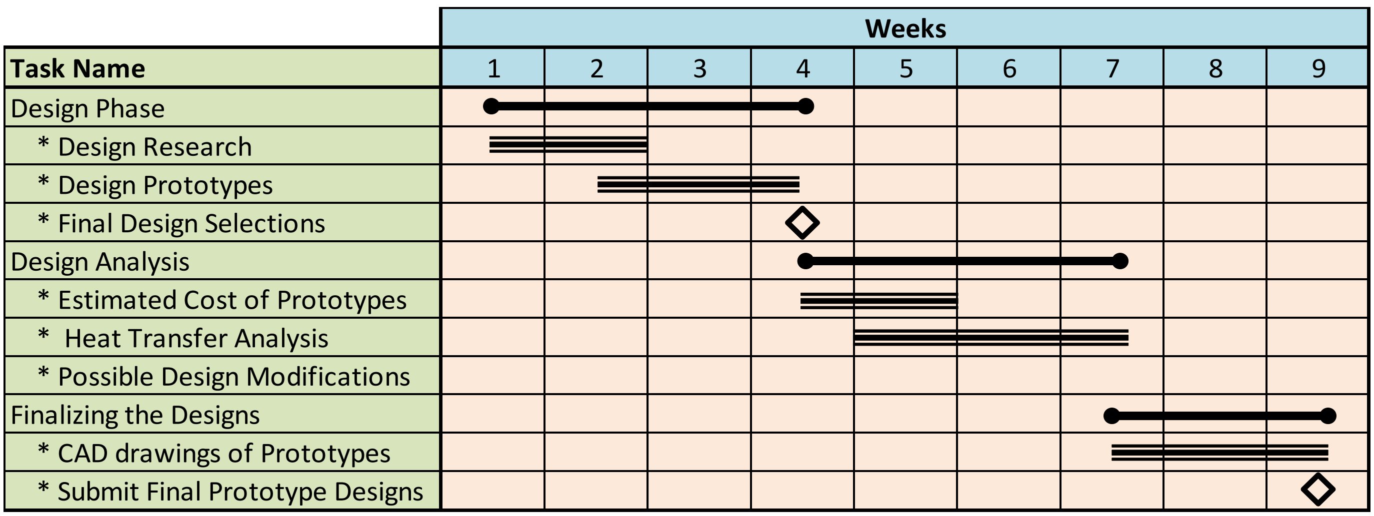

Figure 6: Fall 2013 Project Planning and Design Phase

The design phase will start at the beginning of the second week of October and end at the last week of October, and the design phase will include the following tasks:

- Design research will take a place during the period 10/09/2013 to 10/18/2013
- Design Prototypes will start at the 16th of October and end at the 31st October.
- Final design selection will be at the 31st of October.

The design analysis can be started after finishing design phase, and this task will happen between the beginning of November and end at third week of November

- Estimated cost of the prototypes will take a place during the period 11/01/2013 to 11/09/2013
- Heat transfer analysis will start at the 3rd of November and end at the 20th of November

- Possible design modification will be made before the 20th of November

Finalizing the design will start right after we finish design analysis and end at the end of the fall semester.

- We will start the CAD drawings of prototypes on the 21st of November and end on the 7th of December.
- Submit final prototype design at the 7th of December

Figure 7 below is the estimated timeline of the project for the Spring 2014:

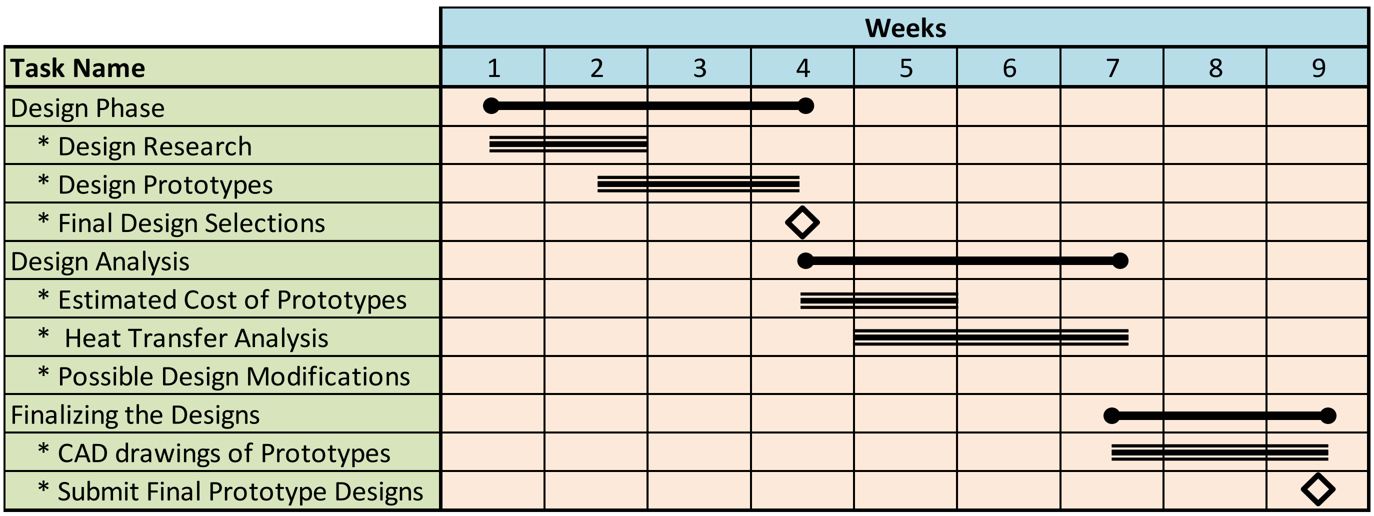

Figure 7: Spring 2014 Construction and Testing Phase (Estimate)

We are going to gather materials between 01/08/2014 and 02/05/2014 and that include:

- Budget planning will be placed during the period 01/08/2014 to 01/17/2014.
- Organizing a list of materials for the prototype will take a place between the 01/15/2014 and 01/22/2014
- The estimated date of receiving materials is the 5th of February 2014.

Construction of prototypes will start on the 6th of February 2014 and end at the 5th of March 2014.

We are going to start testing our prototype between the 19th February 2014 and 20th march 2014 and that include:

- Gathering data from testing will take a place during the testing time.
- Between 02/27/2014 and 03/20/2014 a modification to prototype will be made.

- Retesting prototypes will take a place during the period 03/13/2014 to 03/20/2014.

The final presentation of the prototypes and their test results should be done and ready by the fourth week of March.

13.0 Conclusion

The need that is driving our project is that the amount of power usage to keep the interior of large buildings at a comfortable, cool temperature is too high.

In order to find a way to reduce this power usage, our team will be researching and constructing prototypes different types of roof systems that will help buildings to maintain a constant internal temperature. The two different types of roof system prototypes that will be constructed are the active and passive roof systems. Where the passive roof system has stationary reflective panels and the active panels are moved by a solar tracking device, and then both of these will be compared to the control prototype which just has a white painted roof.

For our project we have two clients and they are Dr. Michael Shafer and Grant Masters, and our team will be working closely with Mr. Masters during the design and construction phase of our three roof system prototypes to ensure that all of the client needs are met. With the top priority of the client needs being to produce low cost prototypes' that use a minimal amount of power to operate.

We expect the design phase for this project to take approximately nine weeks with the first week starting this week, and we expect the construction and testing phase next semester to take approximately thirteen weeks. During the testing phase of this project the prototypes will be tested outdoors to not only test their effectiveness but also to test how well they are able to withstand the environmental elements.

References

[1] M. Shafer, Interviewee, *Project Intro and Passive/Active Roof Designs.* [Interview]. 1 October 2013