24 (7)

The Effect of a Roof Shingle's Color on the Temperature of the House

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Experimental Model

#8

I. Introduction

My father likes to make bold statements, he likes to appear like he knows things, and he likes to share his information with me. I always take everything he says with a grain of salt, because I never know where he's gotten this information. I can remember one time he told me that if 25% of the world's population painted their roof tiles white, global warming wouldn't be a problem. Now I have no idea where that information came from, but the idea sparked an interest in me. I started asking lots of questions, which all boiled down into my research question for this experiment: **What is the best color of shingles to use on a house, in order to keep the house cool during the day, but also retain heat during the night?**

The albedo, or reflection coefficient, of a surface is highly dependent on the color of the object. The equation for albedo is as follows:

$$a = \frac{energy\ reflected\ by\ a\ given\ surface\ in\ a\ given\ time}{total\ energy\ incident\ on\ the\ surface\ in\ the\ same\ time}$$

An object that is a certain color appears that way because it is reflecting the light waves of the seen color off of it and absorbing the rest of the colors. White is a combination of all colors, so therefore it is reflecting all of the light waves off of it and has a high albedo. Black, on the other hand, is the lack of color, it is absorbing all of the light waves, so it has a low albedo. Because of this, black heats up more than white or any other lighter color. Metallic colors also reflect a lot of light and have a high albedo.

By finding the information of which color keeps a space the coolest in a heated setting, but also retains heat in a cool setting, I can determine which color would be the most efficient to tile roof of a house. The reasoning behind checking temperatures in both a heated setting and cool setting is because during summers a cool house is desired, but during winters a warm house is best. If only one of those was researched it would be completely neglecting a population, either in a warm, cold or mixed climate. I predict that a moderate color, grey, in between white and black would be best to keep a house cool, yet still retain some heat.

II.Methods

To start off this experiment I created a model home (Photo #1). And its roof. The house had four different roofs, each with their own color. I cut the roof tiles out of the same piece of asphalt shingle. I spray painted them, each with two coats, white (Photo #2), grey (Photo #3), metallic silver (Photo #4), and left one its original color, black. This small cardboard cube acted as a home for the experiment. This limits the experiment's accuracy in that the data collected will not exactly reflect the data that would be collected if it were a real house. However at the same time it gives an estimation for the data that would be collected and it much easier to conduct. The model home is a good preliminary experiment to see if further research should be done.

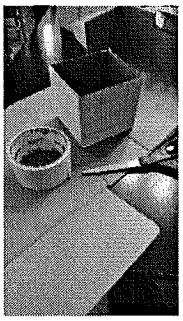


Photo #1

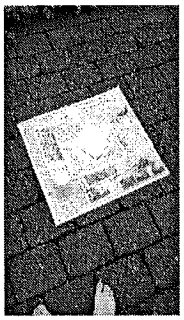


Photo #2


Photo #3

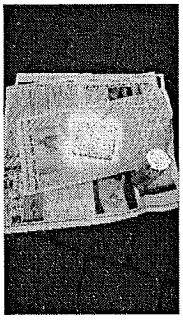


Photo #4

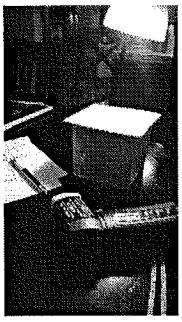


Photo #5

To gather data I would first measure the starting temperature of the roof tile and the floor of the house (always in the center), then I would place it under a light, with the roof tile on top. I recorded temperatures at 5, 10, 20, 30, and 60 minutes, as well as, 5, 10 and 20 minutes of cooling. When it was time to measure the temperature, I would turn the light away from the house, and first measure the roof tile, then remove it and measure the floor, place it back on, shine the light on it, and let the heating continue. The set up can be seen in Photo #5, the tile is placed on the house, the lamp above it at a fixed height, and the infrared thermometer is sitting in front of it.

Some implications of this experiment that I had to consider were health hazards or stains with the spray paint, and injuries from cutting the roof tiles or burning myself on the lightbulb. To avoid an incident with the spray paint I placed the tiles on several layers of newspaper. I did this in my backyard to avoid inhaling the fumes. When cutting the roof tiles, I pulled the blade away from me and not towards me, so if I slipped I wouldn't injure myself. To avoid burning myself on the lightbulb, I placed the setup of the experiment far away from me so I wouldn't bump into it, and when I measured the temperature, I was aware of my hand's location in relation with the light.

For purposes of replication please refer to the following:

Materials:

- Asphalt shingles (to be painted different colors)
- Infrared thermometer
- White, grey, and metallic silver spray paint
- Newspaper
- Cardboard
- Duct tape
- Light with a 25W light bulb

The model house was created out of four 5 inch by 5 inch cardboard walls and one 5 inch by 5 inch cardboard base. It was then completely wrapped in duct tape to hold it together and also for added insulation. The top of the model home was left open.

Four different 6 inches by 6 inches roof pieces were cut out of the same large piece of asphalt shingling. The roof tiles were placed each on their own few layers of newspaper in an outdoor setting. They were then spray painted white, grey and silver respectively, and then another layer was sprayed on

the tiles after they had dried. One tile was left unpainted. Once the tiles had completely dried the experiment was set up.

The model home was placed on a flat surface with the light above it. A roof tile was placed on top of the model home. Before the light was turned a starting temperature was taken. The infrared thermometer measured the temperature of the roof and floor of the house in the middle of each surface and the data was recorded. Next the light was turned on and after 5 minutes the temperatures were measured in the same manner and the data was recorded. To measure the temperatures accurately the light was pointed away from the model home, and the roof had to be quickly removed to measure the temperature of the floor. Then the roof was quickly placed back on the model home, and the light was pointed on it once again. These measurements were conducted and recorded at 0, 5, 10 20, 30 and 60 minutes. After the 60 minute measurement, the light was turned off and cooling temperatures were measured and recorded in the same way at the times 5, 10 and 20 minutes.

After all data was recorded, the model home had to sit until it reached its previous starting temperature before the experiment could be conducted again with a different roof tile. All recorded data was graphed on Excel for each heating tile color and each cooling tile color. A graph was also made for the change in roof temperatures, using the temperature at staring and at 60 minutes.

III. Results and Analysis

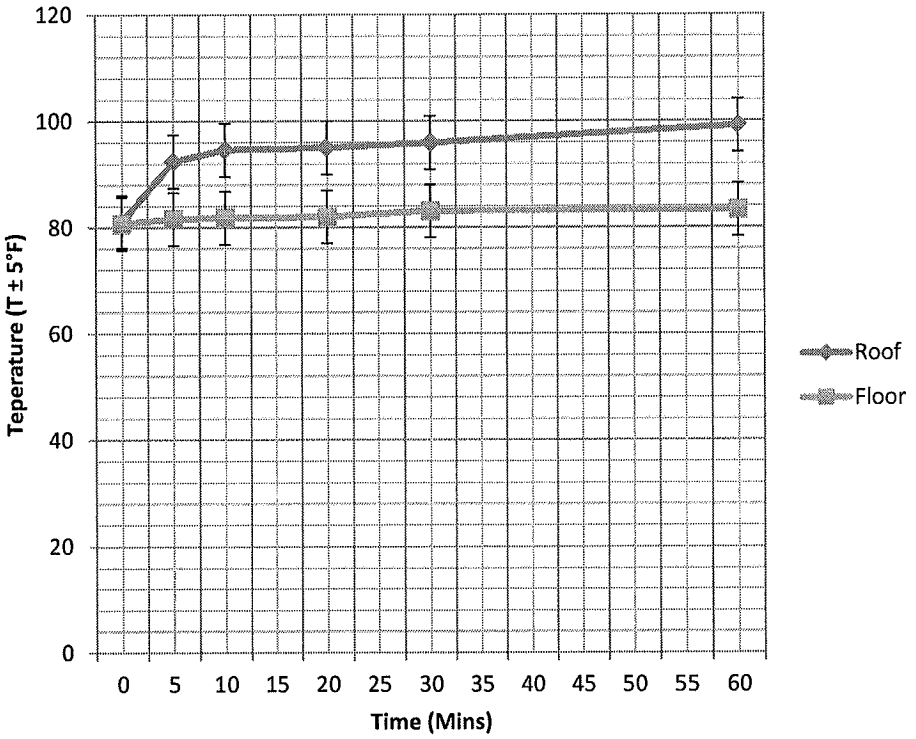
Table #1: Roof Tiles Temperature Heating Up (T ± 5°F)

		Starting	5 mins	10 mins	20 mins	30 mins	60 mins
Black	Roof	81.1	92.4	94.6	95.0	95.9	99.1
	Floor	80.7	81.6	81.8	82.0	83.1	83.3
White	Roof	80.4	86.0	90.1	91.7	91.9	92.8
	Floor	79.5	80.6	82.0	80.9	81.1	81.6
Grey	Roof	77.1	88.1	92.1	93.2	95.5	96.6
	Floor	76.6	78.4	78.6	78.9	80.4	81.1
Silver	Roof	81.1	82.5	84.9	83.4	83.3	83.6
	Floor	79.8	82.2	82.5	81.8	81.6	82.7

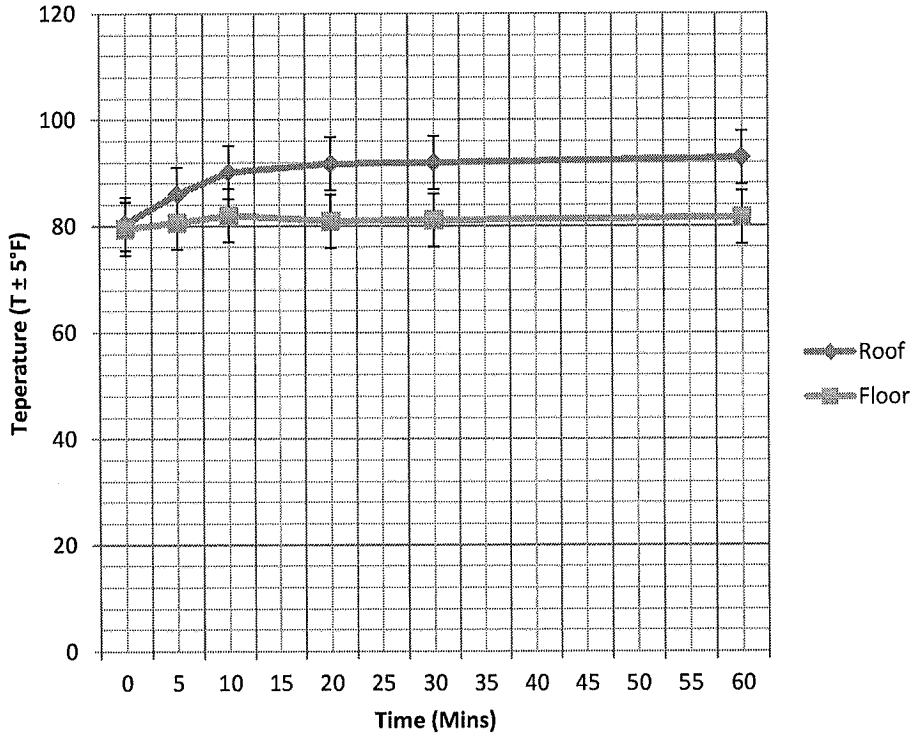
Table #2: Roof Tiles Temperature Cooling Down (T ± 5°F)

		5 mins	10 mins	20 mins
Black	Roof	85.1	82.9	80.9
	Floor	82.0	81.6	81.3
White	Roof	82.9	80.6	79.3
	Floor	80.2	80.0	80.0
Grey	Roof	84.5	79.5	79.3
	Floor	79.8	79.7	79.3
Silver	Roof	82.7	82.0	82.0
	Floor	82.0	82.0	82.0

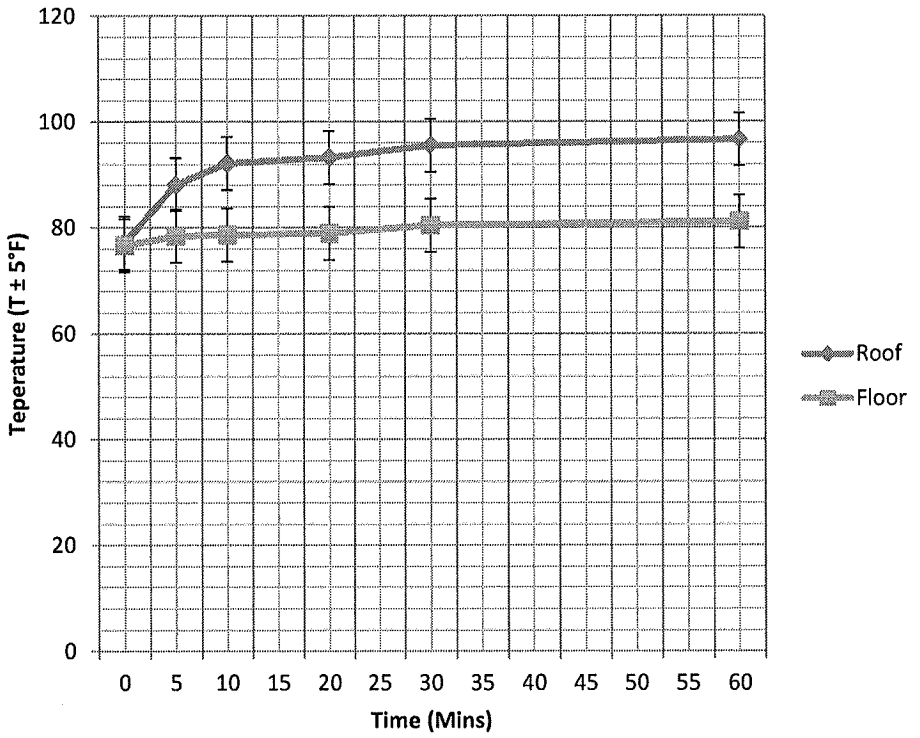
Graph #1: Black Roof & Floor Temperature vs. Time



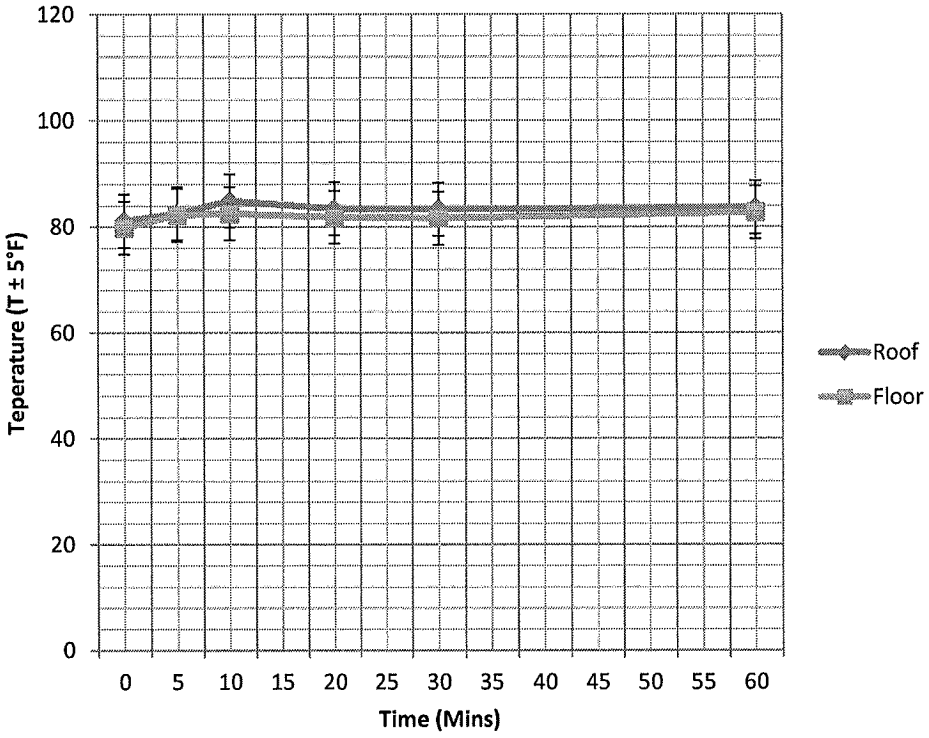
Graph #2: White Roof & Floor Temperature vs. Time



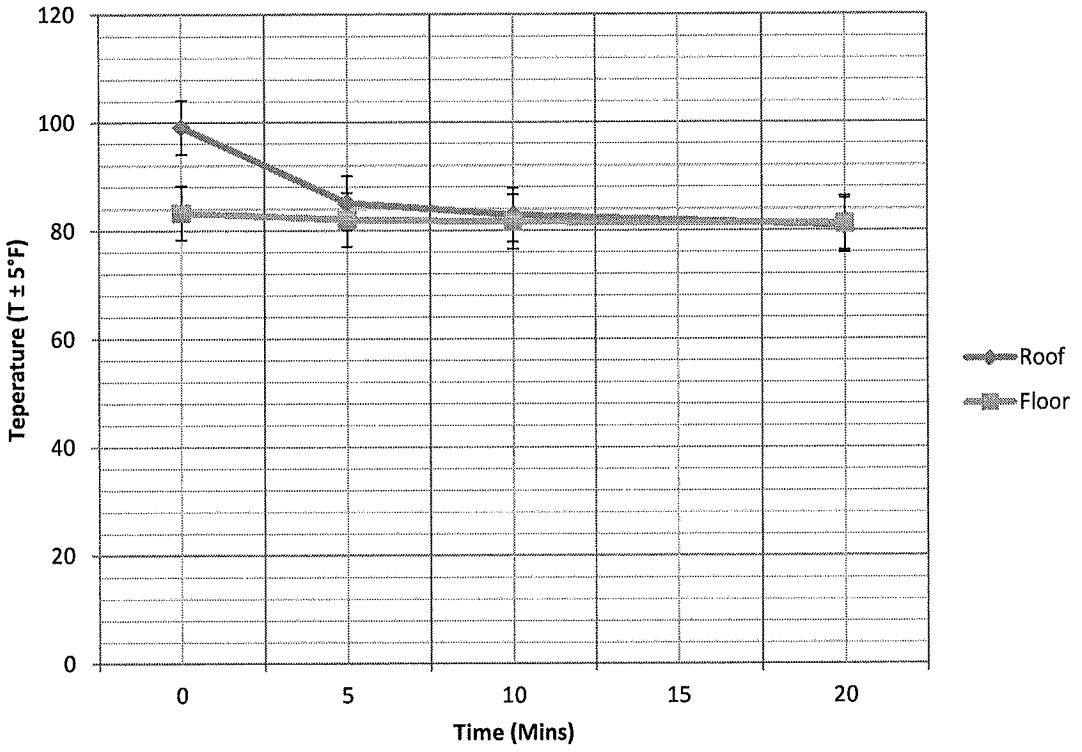
Graph #3: Grey Roof & Floor Temperature vs. Time



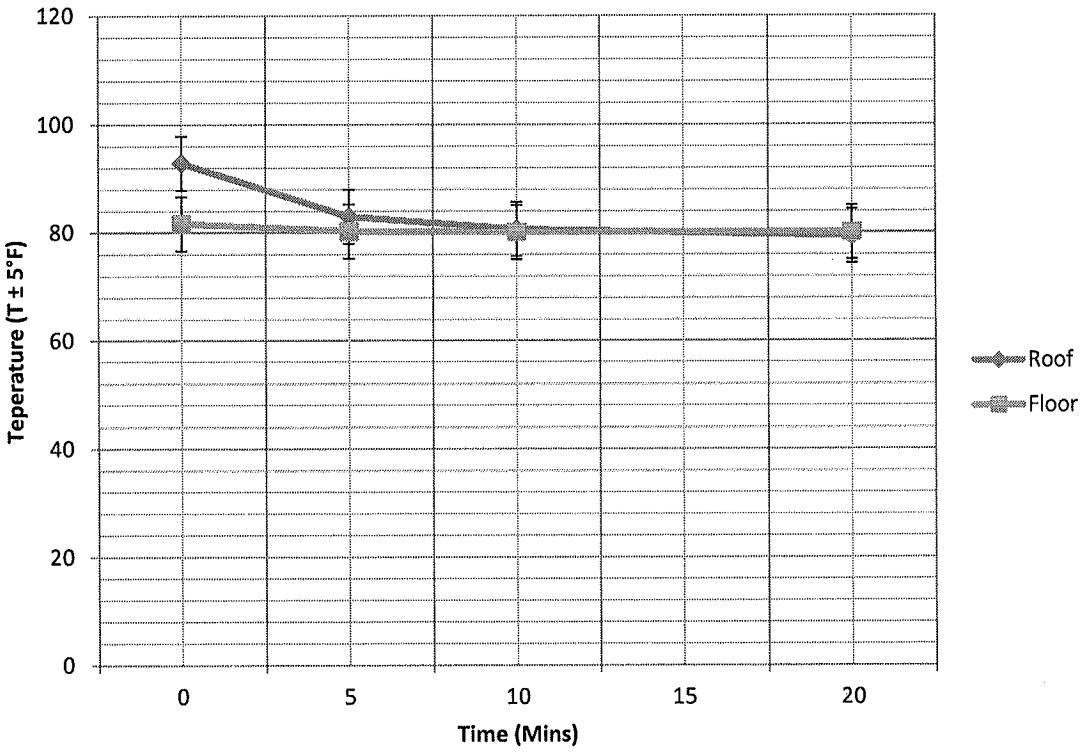
Graph #4: Silver Roof & Floor Temperature vs. Time



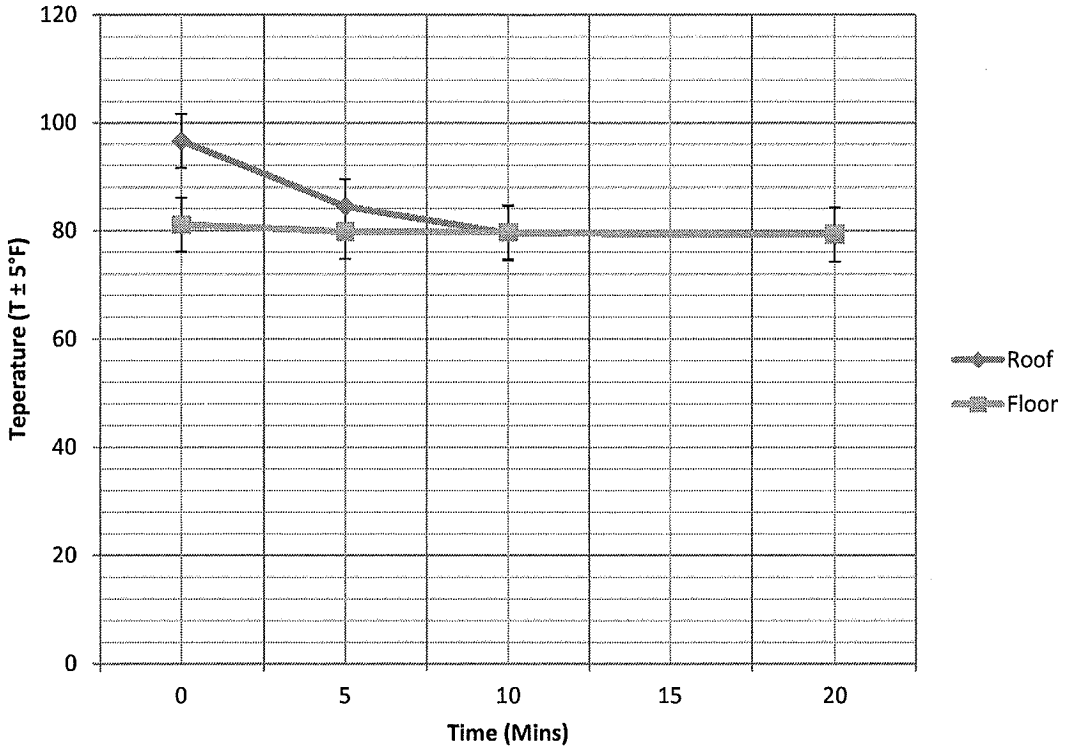
Graph #5: Black Roof & Floor Cooling Temperature vs. Time



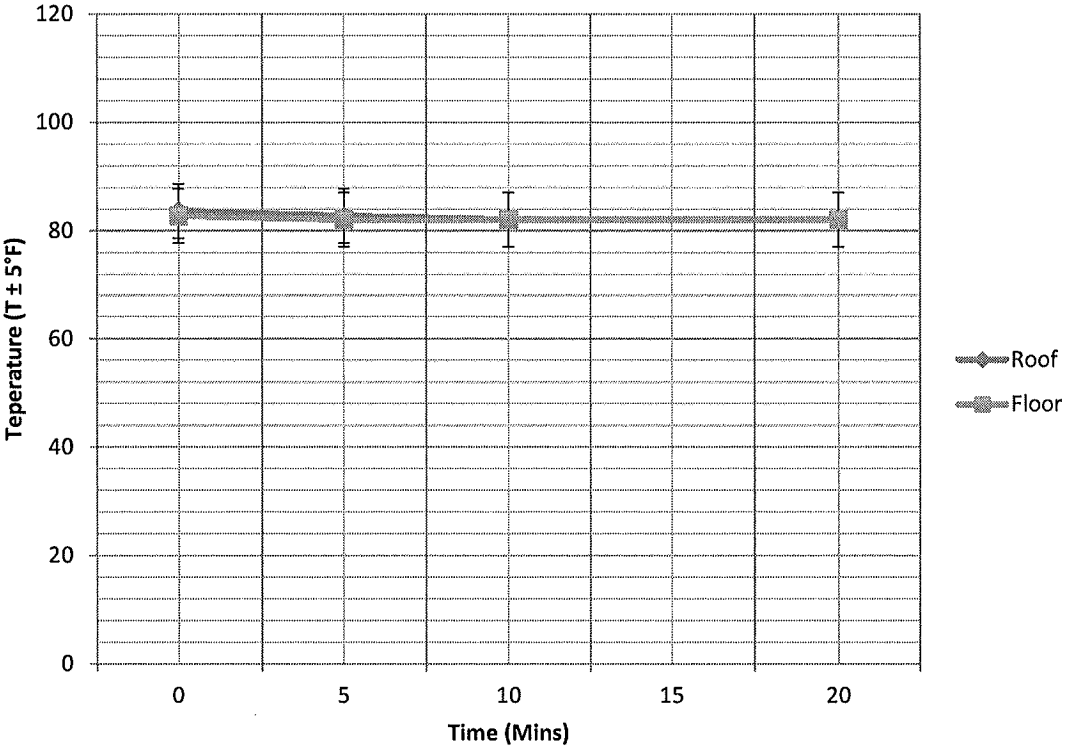
Graph #6: White Roof & Floor Cooling Temperature vs. Time



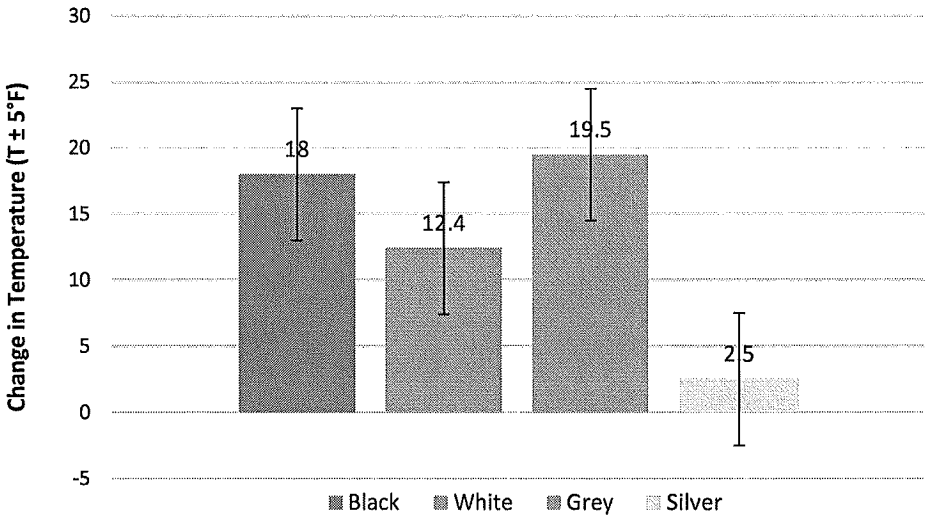
Graph #7: Grey Roof & Floor Cooling Temperature vs. Time



Graph #8: Silver Roof & Floor Cooling Temperature vs. Time



Graph #9: Change* in Roof Tile Temperatures



$$* \ \Delta T_{roof\ tile} = (roof\ T\ @\ 60\ mins) - (roof\ T\ @\ starting)$$

To properly analyze the data from this experiment I have to take into account the uncertainty of my data. For the time measurements, the uncertainty is ± 5 seconds; however because it is such a small amount of time, it has no effect on the data. For the Temperature measurements, the uncertainty is ± 5°F.

When cooling the all of the different roof tiles returned to almost their original temperature. The starting temperature of the roof for black was 81.1°F, and after it was heated and cooled the temperature was 80.9°F, almost exactly the same. This trend continues with all of the roof tiles. This shows that the heat retained in the cold is not dependent on the roof tile color. So unfortunately I am unable to answer that piece of my research question.

The starting temperatures for the roof tiles, and floor are all different, so I need to take that into account when looking at the temperature of the floor and roof tiles in heating. Refer to Graph #9 to see the change in temperatures for the roof tiles. The tile with the greatest change is grey at 19.5°F and the tile with the least change is the silver one, with a change of 2.5°F.

IV. Conclusion and Evaluation

When looking back at my research question (What is the best color of shingles to use on a house, in order to keep the house cool during the day, but also retain heat during the night?), I am not able to answer the second part of it. The temperature always returns to its starting point regardless of the roof tile color. But I am able to answer the first part. The roof tile color that remains the coolest is the silver one, the change in temperature was only 2.5°F, it clearly has the lowest change, with the one above it being at 12.4°F (the white roof tile).

Most of my data results would be accepted scientifically. Because of its high albedo the silver heats up the least, my data is in line with that. The one that would heat up the next least is white, my

data is also in line with that. The incongruity of the data is between the grey and black tile. Black has a lower albedo than grey, so therefore black should have the highest change in temperature, though that is not the case, grey does. That is the only discrepancy with my data and actual scientific knowledge. However because of the uncertainty values and error bars of my data, it is all still accurate. The change in temperature the black tile could be anywhere between 13°F and 23°F. While the change in temperature for the grey tile could be 14.5°F to 24.5°F.

Every object at a temperature above absolute zero radiate infrared rays. When the light is turned on it begins to emit more infrared rays. These rays radiate out of the light in a straight line until they are absorbed or reflected by another object, or in this case, the roof tile. The black tile absorbs a lot more of these rays than the silver tile, which reflects a lot of them. That is why the black tile heated much more than the silver one. When the rays are absorbed the molecules on the surface are excited and start moving quickly. This perpetual jiggling motion of the atoms result in the atoms colliding and speeding up other atoms, this creates heat. This motion is called Brownian Motion. As the atoms collide with each other they heat up the whole roof through conduction. The conduction continues through the air, but it is much slower because air has a low density and finally the floor is heated at well. Since much more of the infrared rays were reflected off of the silver tile than the black tile, there is much less heat being transferred and therefore its change in temperature is a lot lower.

To fully evaluate my investigation I must look at its strengths and weaknesses. One of its strengths is that it was a very easy experiment to conduct and it was within the scope of my understanding, which is a significant factor because it means that I was less likely to make mistakes, and if I did make a mistake, I could easily tell. Its weaknesses are mainly a multitude of factors which I could not control. First of all, the infrared thermometer isn't a very accurate way to measure temperature, the temperature would be bouncing around and it changed depending on where I pointed it, which is why the uncertainty value was so large. To solve that I would need some other, more accurate, thermometer that measures surface temperatures. Second was the temperature of the environment, the experiment was done at the same location, but depending on the weather, the air would be warmer or cooler. This could be solved quite easily, the experiment would have to be done either on the same day, which would be very time consuming, or in a closed environment, with no windows, so it wouldn't be subject to temperature change. Time is another problem, when it was time to measure the temperature I would direct the light in another direction, and measure the temperature, but within moments it would start to cool. Even moving as fast as I could, the temperature was probably not as accurate as it could have been. This problem can't be entirely solved, having more people working on the experiment, each person with their own job, would improve it a little. Overall this experiment was quite strong, it didn't gave too many weaknesses, and the ones it did have are easily solvable.

While this experiment may be concluded, there are still many ways it could be taken further. Now knowing that painting a rooftop silver would keep a house the coolest, I could continue the investigation with just that information. Looking into other metallic materials, not just paint could be one option. I could do an experiment to see how cool silver actually keeps houses and calculate the money and energy saved on air conditioning in different climates, and for what climates would it make the most sense to have a metallic roof. This experiment was just the beginning to a very interesting and useful series of investigations.

V. Works Cited

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