Third Party Evaluation of "Cool Roof" Technologies

Texas State Energy Conservation Office

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Prepared by
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Texas Center for Applied Technology
Texas Engineering Experiment Station

Table of Contents

Table of Contents 2
List of Figures 2
List of Tables 2
Acknowledgements 3
Executive Summary 3
Introduction 4
Methodology 5
Findings 14
Conclusion 17
Appendix A – Data Logger Graphs 19
Appendix B – Literature Review 37

List of Figures

Figure 1. Cost for utilities at Madison High School "Portable City" 5
Figure 2. Madison High School Portable Layout 6
Figure 3. Bard Wall Mounted Packaged Heat Pump 7
Figure 4. Cool Roof Coating on Near Facility 7
Figure 5. Typical Floor Plan 8
Figure 6. Current Sensor Location 9
Figure 7a. Portable 119 Data (Without Cool Roof Coating) 10
Figure 7b. Portable 120 Data (With Cool Roof Coating) 10
Figure 7c. Portable 121 Data (Without Cool Roof Coating) 11
Figure 7d. Portable 122 Data (With Cool Roof Coating) 11
Figure 8a. Portable 121 Data – Cooling (Without Cool Roof Coating) 12
Figure 8b. Portable 122 Data – Cooling (With Cool Roof Coating) 13
Figure 9. Insulation in Portable Rooms 13
Figure 10. Comparison of Motor Amps With and Without Cool Roof Coating 14
Figure 11. Potential Energy Savings over 2 Years 15
Figure 12a. Power Outage Response – Plenum vs. Room Temperature 16
Figure 12b. Power Outage Response – Supply vs. Room Temperature 16
Figure 13. Cost Reduction over a School Year 17

List of Tables

Table 1. Savings Comparison – Portable Buildings
With and Without Cool Roof Coating 15

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The staff of Texas Engineering Experiment Station would like to thank the Northeast Independent School District, particularly Madison High School, for their help and patience during this study. Special thanks to Principal, Chris Thompson, and his staff, and Paul Raabe the district Energy Manager. We are especially grateful to the students and teachers, in maintaining the integrity of the equipment and helping to facilitate the data gathering process. Your support has been greatly appreciated. Your faculty, staff, and students have been a pleasure to work with during the course of the study.

Executive Summary

The Texas State Energy Conservation Office (SECO) is interested in providing practical and affordable ways of increase the energy efficiency of portable classroom buildings in wide use by public school districts in the State of Texas. In San Antonio alone, the two largest districts, Northside ISD, and Northeast ISD, have over 1,000 of these portable classroom structures in constant use at a multitude of levels throughout each district. These buildings provide a fast, cost effective ways for districts to rapidly expand their capacity; however, due to their nature of construction, they are particularly susceptible to characteristics that waste energy, thus depriving schools of badly needed operations and maintenance dollars. The objective of SECO is to provide access to technologies that reduce the energy consumption of these structures.

With this background in mind, SECO has actively sought out tools, techniques, and products that can assist school districts in minimizing their energy costs. One such technology is the idea of "cool roofs." These products provide the capability to increase the thermal performance of buildings; thus reducing energy costs required to maintain occupant comfort. SECO recently became aware of a reflective coating called Microteja®. The claims and analysis shown by local industrial users of the coating crated high interest by SECO engineers and staff: therefore, SECO is interested in providing additional data that can be used by school districts in evaluating these "cool roof" technologies.

Based on comparison and accessibility, it was decided that the Madison High School "portable city" would be the site for the study. Madison High School is in the Northeast ISD located at 5005 Stahl Road in San Antonio, Texas. Four adjacent portable buildings were selected for the study. The "cool roof" applicator was notified of the selection so that facility preparation and coating could take place. Once this was done, efforts were directed to ordering and installing appropriate instrumentation for the study and planning the layout of sensors and loggers to optimize data gathering opportunities. Installed HVAC equipment details were located and reviewed. Utility bills were provided by the distinct and a preliminary energy use profile was developed. This information was useful in determining an energy use baseline, and together with initial data logging files will complete this portion of the study.

It appears from the data we observed that the cool roof coating does mitigate the plenum/attic temperatures in the cooling months. This reduction in temperature appears to reduce the work of the compressor which consecutively reduces energy costs. The range of savings for a portable classroom based on this energy reduction can range from 0.4% to 17.3% depending on weather, equipment and set points.

Introduction

The Brooks Energy and Sustainability Laboratory (BESL) is a consortium of professionals from the Texas Engineering Experiment Station (a unit of the Texas A&M University System), and the Georgia Tech Research Institute (a unit of the Georgia Institute of Technology). This unique team of researchers brings the academic strength of these two institutions to bear on solving real world problems in our communities (local, regional, national and global) by providing technology transfer services in the areas of energy efficiency, building sustainability, and indoor air quality. BESL and our customers improve the performance of their facilities and reduce operating costs by applying the technologies and practices perfected "in the lab."

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In this report, TEES has provided a third party evaluation of the Microteja® coating for SECO. TEES has as its organizational mission not only to provide independent services to clients such as the SECO, but to help develop and transfer technologies into the private sector. TEES is also committed to working with providers of the technologies involved in these projects to help them meet customer's requirements and provide best value to the customers and the citizens of the State of Texas.

Methodology

The cost for a school to utilize a "portable city" can be a substantial contributor to the total energy cost. In a Florida study, portables accounted for 11% of the energy budget for the public schools there. Figure 1 below displays the monthly cost for the portable city at Madison High School over a two year period. The annual cost at Madison High for the 2005-2006 school year was $14,883.14 for 10 portables. The Northeast ISD has over 300 portables throughout the district. Based on these numbers, the potential savings from the application of cool roof is worth investigating.

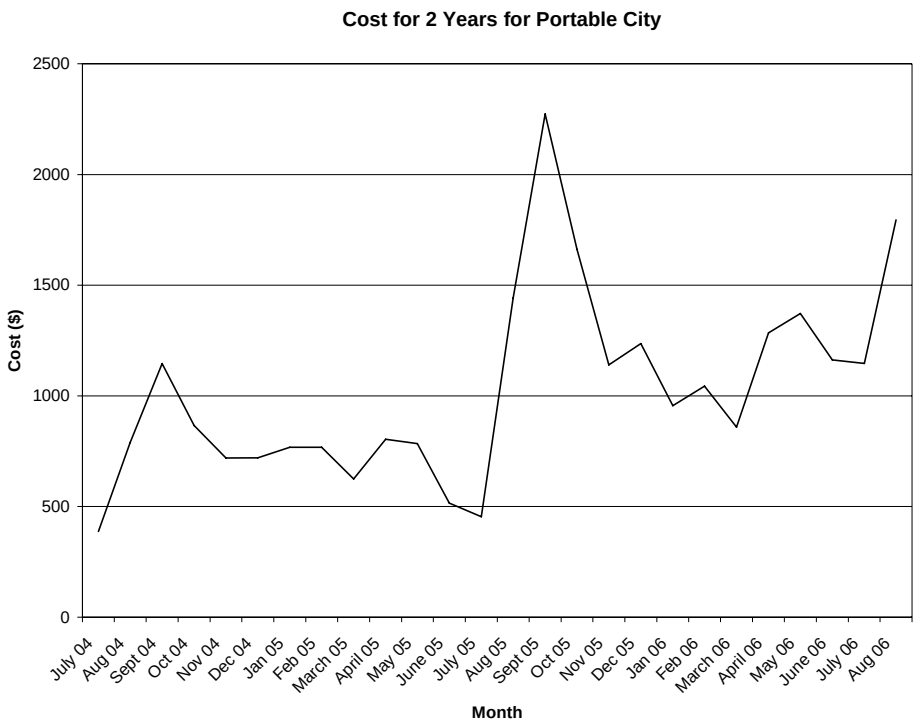


Figure 1. Cost for utilities at Madison High School "Portable City"

The layout of the portables at Madison High School is shown in the diagram in Figure 2. Four adjacent, portable classroom units were selected for testing in order to minimize any variation in incident sunlight/heat effect. The cooling units are built by Bard Manufacturing (Figure 3) and are ducted supply and ducted return systems. Outside air for each unit was factory set at minimum, and thermostats were checked for calibration prior to the start of the study. The A/C units were checked and commissioned prior to the start of the study.

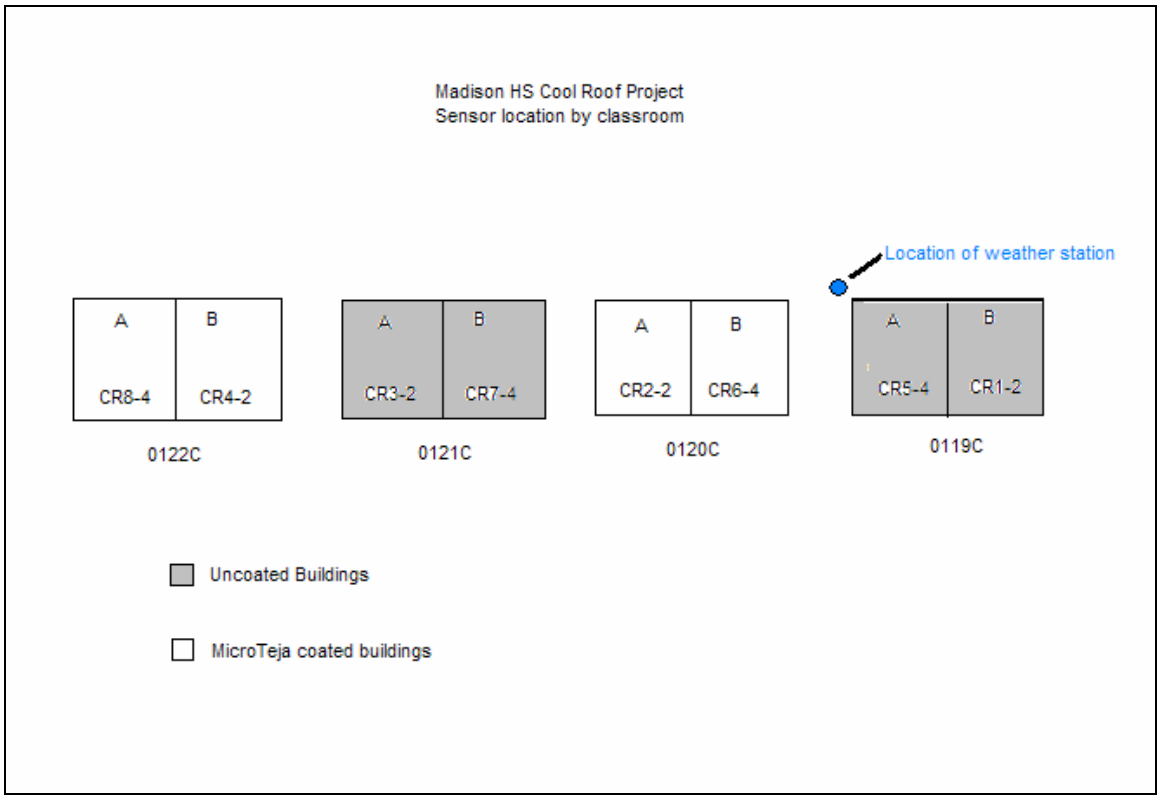


Figure 2. Madison High School Portable Layout

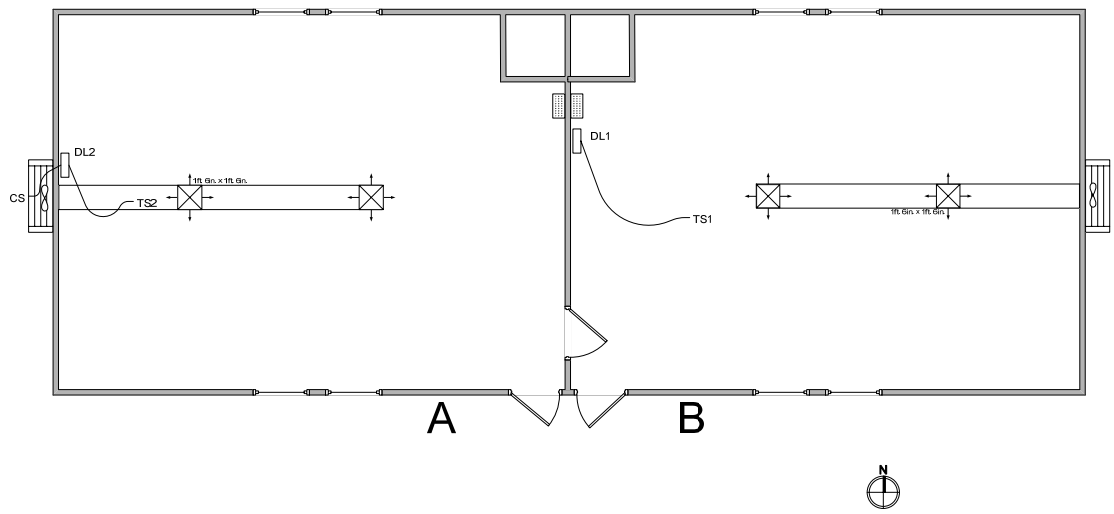
As mentioned above, these portables were all in an open area with no shading effect from nearby buildings or structures. We wanted to capture as many parameters as possible for two buildings of each type to make sure that there was not significant deviation in the data collected. The cool roof coating was applied to two portables, and two other adjacent portables were left uncoated. Due to constraints on the number of remote data loggers available for the study, the total number of facilities in this investigation was limited to four portable buildings with a total of eight classrooms.

Figure 3. Bard Wall Mounted Packaged Heat Pump

The roofs of the portables were prepped, primed and the cool roof coating was applied by the manufacturer with the entire process being completed by 12 August 2005. The process of preparing the roof for application consisted mainly of a quick, low pressure power wash to remove loose debris from the roof surface. The manufacturer indicates that the coating is compatible with many existing roof components such as shingle roof, rock ballast, and corrugated metal roofing. This final process of applying the cool roof was a quick one day application for two roofs on the test facilities (Figure 4).

Figure 4. Cool Roof Coating on Near Facility

Each building is a double classroom structure of approximately 1480 gross square feet. The sensors and loggers are from Onset Computers Incorporated and were either two channel temperature external sensor type or four channel temperature/relative humidity, with two external inputs. Additional remote wired temperature sensors were attached to external channels to record parameters that were located in the HVAC unit, the supply air duct, and the above ceiling temperature. Sensor location was determined after initial site investigation and sensors and loggers were placed as indicated on the floor plan shown below in Figure 5. In one room of the portable the sensors and loggers were set up to log amps, relative humidity and temperatures while the other room logged plenum/attic temperature and room temperature. The local mini weather station was installed to record site temperature and relative humidity.



TS - Temperature Sensor (temp/RH)
DL – Data Logger (temp)
CS – Current Sensor (amps)

Figure 5. Typical Floor Plan

Figure 6 shows the location of the current sensor on the compressor. This sensor records the amps for the fan/condenser motor. Based on the manufacturer's sequence of operation, this current value provides information on component runtimes inside the unit and will be added to the manufacturer's compressor rated amps and the motor/evaporator amps to determine cumulative current totals for each unit operating based on logged intervals.

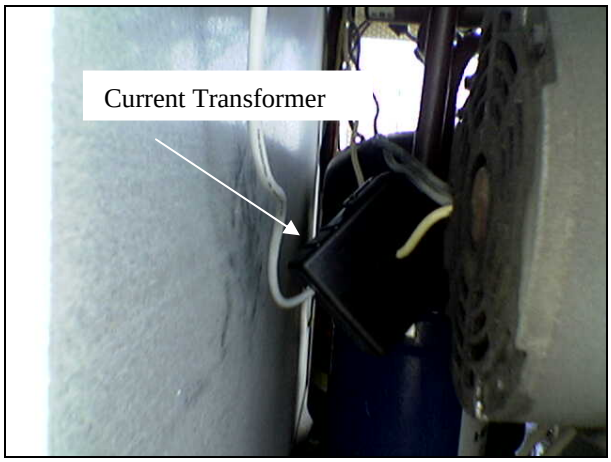


Figure 6. Current Sensor Location

Data logging began on 26 August 2005 and continued until 11 August 2006. The data was downloaded approximately once a month. The initial 30 day period provided data to determine if equipment commissioning was required for any of the test facilities. Based on room thermostat set points and comparison with data downloaded from loggers after this initial period, it was determined that all equipment was operating within acceptable parameters and that extensive commissioning was not required. Space temperature measured inside the classroom is maintained by the thermostat set point and varied between from 62°F to 74°F. During the period of this study, the set point on the thermostat was adjusted to 74°F at each logger download opportunity, but may be readjusted up or down by facility staff as needed. The data logger in the space as well as in the supply air duct registers these changes and records the time of adjustment during the logging interval. The graphs in Figures 7a-7d show a representation of the four portable building temperature data. Portables 119 and 121 do not have the cool roof coating while portables 120 and 122 have the cool roof coating applied. As shown by the data, the plenum/attic space above the suspended ceiling in portable 121, reached 131°F at a time when outside temperature as recorded by the local weather station measured 100°F.

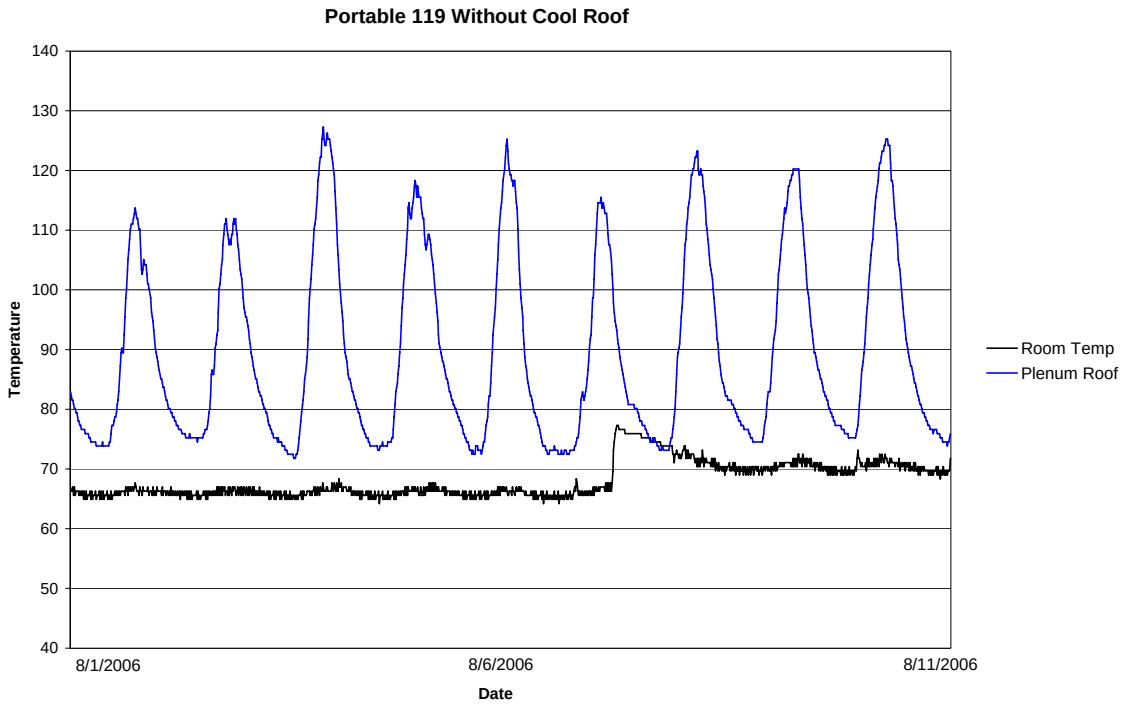


Figure 7a. Portable 119 Data (Without Cool Roof Coating)

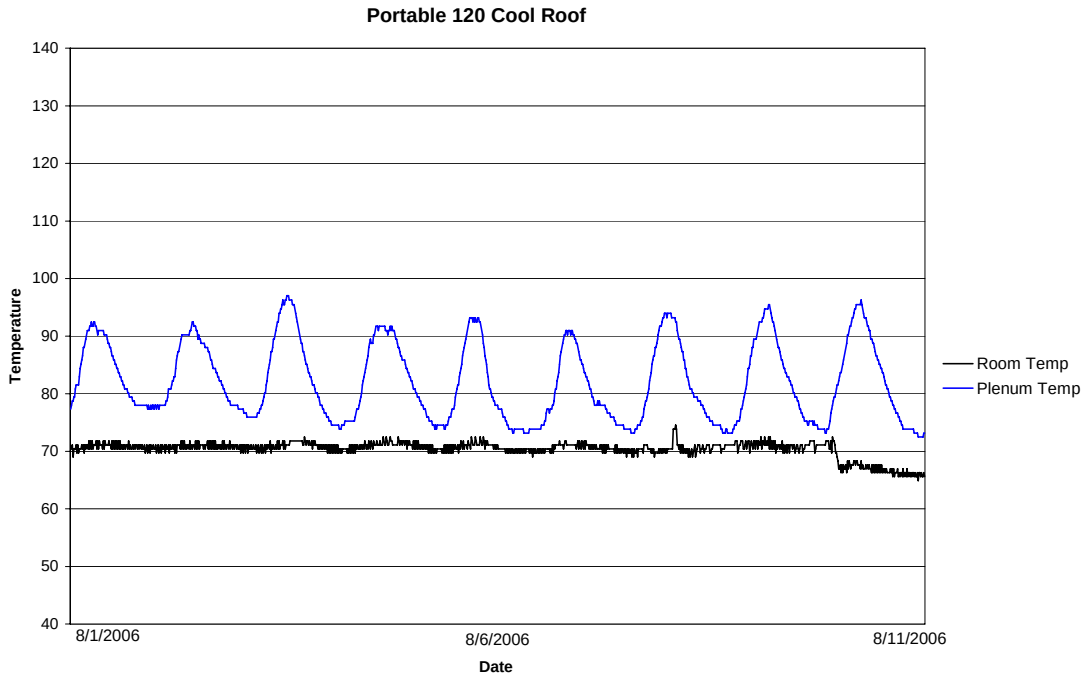


Figure 7b. Portable 120 Data (With Cool Roof Coating)

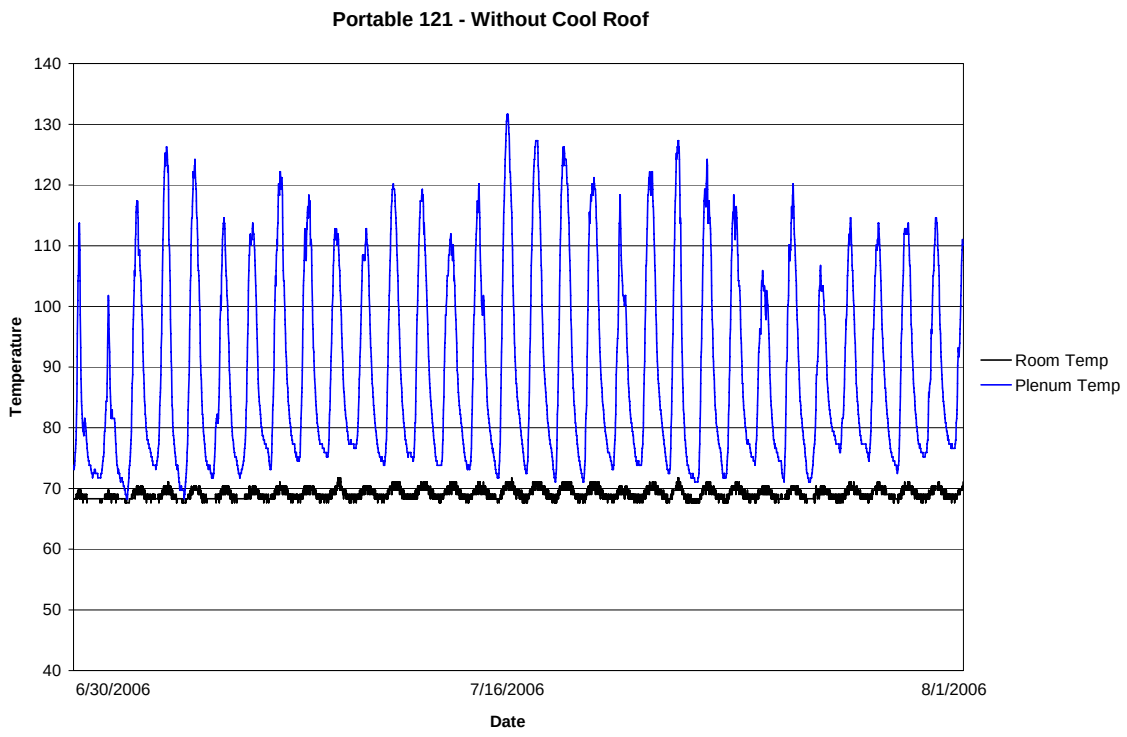


Figure 7c. Portable 121 Data (Without Cool Roof Coating)

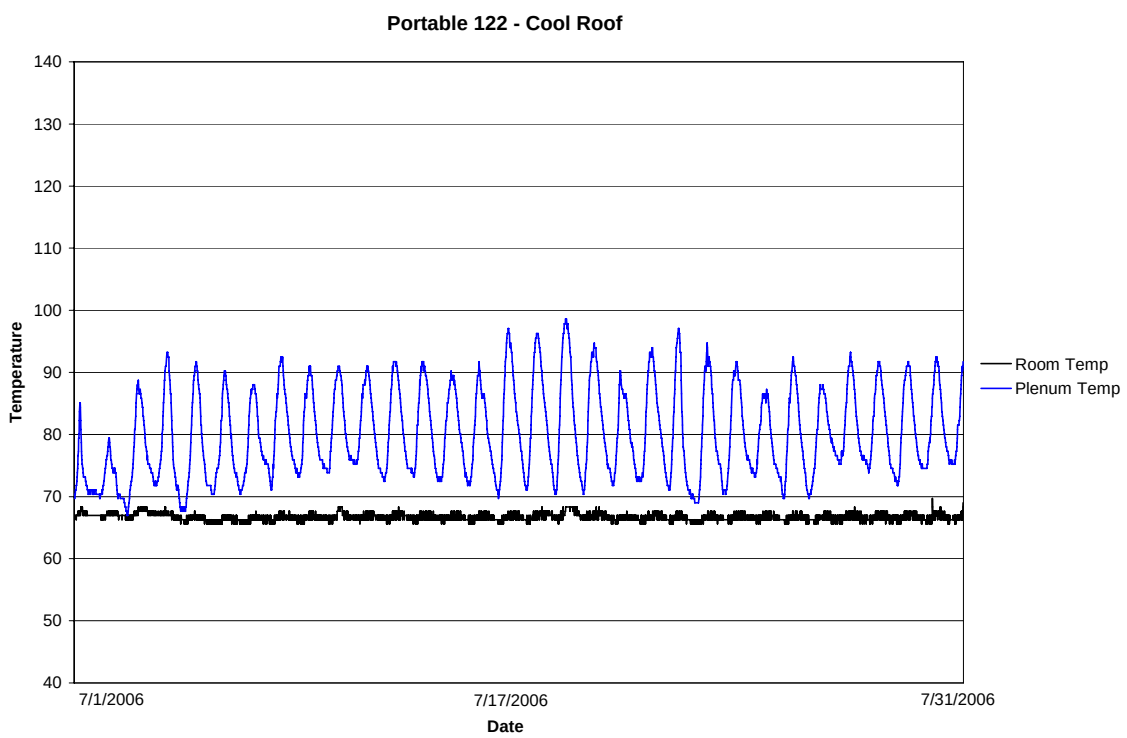


Figure 7d. Portable 122 Data (With Cool Roof Coating)

All measures were equal as mentioned above, and all portables are on the same school site and in the same orientation. It can be seen from the graph of portable 122 that the temperature in the attic space for the same time period was reduced to approximately 98°F. This is a reduction of 33°F when compared to the roof without cool coating.

The next two graphs (Figures 8a and 8b) depict the space and plenum temperatures as outside temperatures begin to cool. For the data shown, outside temperature was recorded between 51°F and 100°F for the highs. On one of the high temperature days, the attic/plenum temperature reached 115°F for the non-coated roof while the coated roof temperature reached 89°F. In the heating months, the roof coating does not show any adverse effect on the portable heating operation, although on extremely cold days it is possible that radiant heat from direct sunshine "may be minimized". Since portable building construction methods may vary widely it is difficult to quantify this impact. It is the intent of this project however to determine the potential effects of cooling equipment energy consumption based on the predominant climatic conditions in the local area. Based on this, it is expected that the cool roof coating is more beneficial during the cooling months, hence the name "cool roof", and for climates that have more cooling degree days reduced energy costs are anticipated.

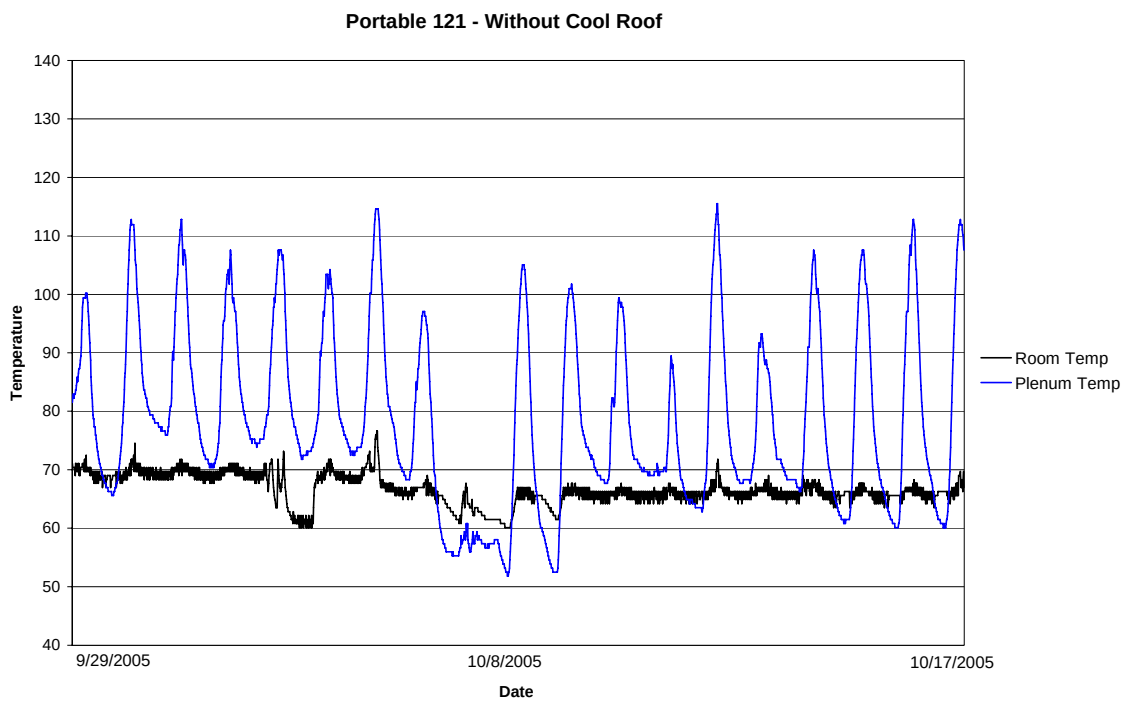


Figure 8a. Portable 121 Data – Cooling (Without Cool Roof Coating)

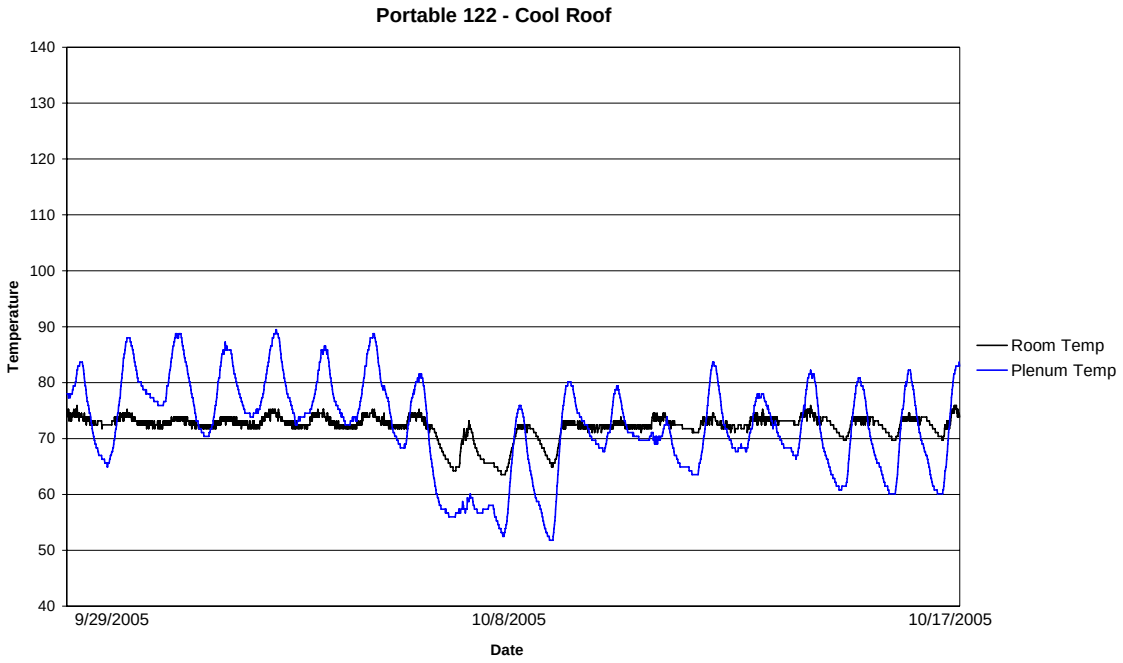


Figure 8b. Portable 122 Data – Cooling (With Cool Roof Coating)

It can be easily assumed that the heat through the structure is transmitted to the interior of the space. The rate of this heat transfer is dependent on the level of insulation above the suspended ceiling. Figure 9 shows the insulation and open attic space in the portable. Many buildings have batt insulation above the ceiling which is missing, or bunched up, so that the heat retarding properties are reduced in those areas. This is most likely a common problem in the majority of portable classrooms. In particular, those portables that are older, or have been moved numerous times, or have suffered roof leakage from rain penetration are susceptible to the insulation migrating to the edges or corners of the roof.

Figure 9. Insulation in Portable Rooms

Findings

The results seen from the data logging indicates the "cool roof" helps keep the plenum/attic temperatures down. We see as much as a 35°F temperature difference from the coated versus the non-coated roof. This lower plenum/attic temperature on the portables with the "cool roof", will help reduce the amount of work the A/C units have to keep them cool them. Therefore, reducing the overall expense associated with operating and maintaining the portables for the school district.

In order to predict the expected savings of the cool roof, we looked at the amps taken from the current sensor to determine the operation of the compressor. An example of the amps from one of the portables is shown below in Figure 10. It can be seen from the graph that the compressor with the cool roof was not running as often as the compressor without the cool roof.

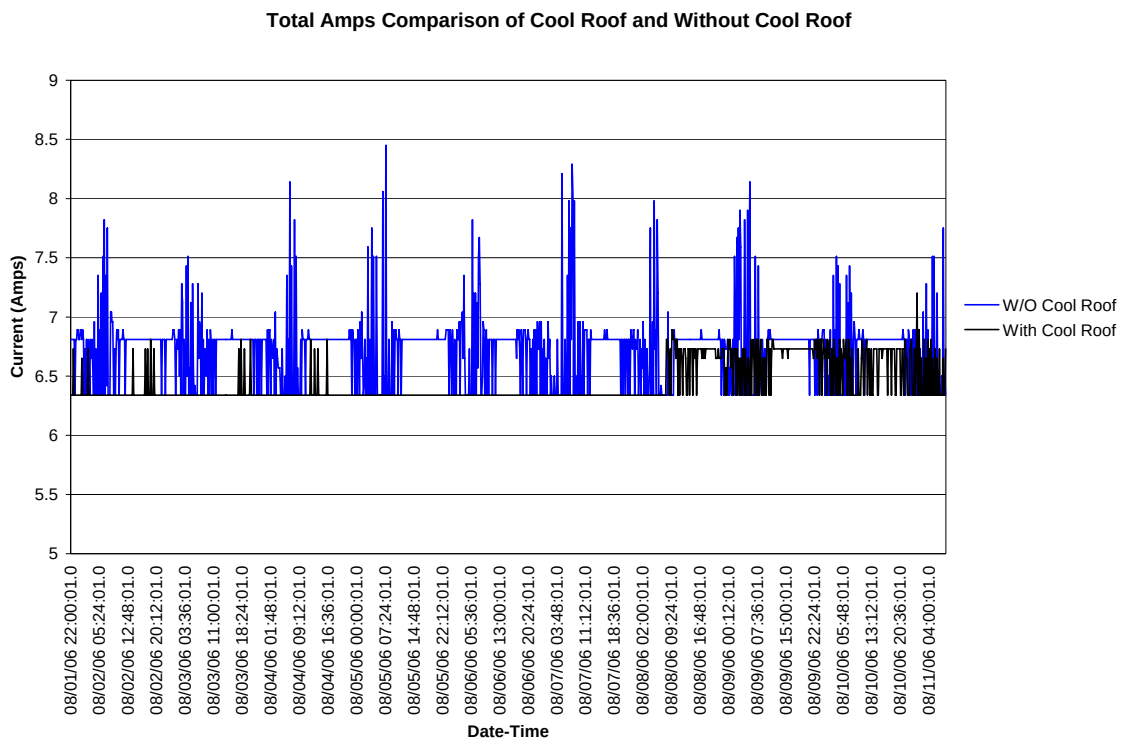


Figure 10. Comparison of Motor Amps With and Without Cool Roof Coating

For the total energy used for a portable, we assumed the HVAC accounted for about 40% of the energy. One of the samplings was taken from September 2005 which was for a continuous 18 day period. During this time period, the compressor in the portable without the cool roof coating ran for 46% of the time while the compressor in the cool roof portable ran for 35% of the time. From these runtime percentages, we could associate an approximate energy cost and calculate the savings from the cool roof. These

different samplings will give an approximation of the potential savings from the cool roof product. This is based on a 6 month cooling cycle. Table 1 shows the results from the comparisons of the portables with and without cool roof for September 2005 and August 2006.

Table 1. Savings Comparison – Portable Buildings With and Without Cool Roof Coating

September 2005	Monthly $ Savings	% Total Savings
119 vs 120	$10.27	5%
121 vs 122	$1.00	0.4%
August 2006		
119 vs 120	$31.22	17.4%
121 vs 122	$27.96	15.6%

This range of savings is based on existing weather, equipment and set points in the portables. The table shows a range of savings from 0.4% to 17.4% over this monitoring period. The graph in Figure 11 depicts the trend for the potential energy savings compared to the actual school energy cost for the portable city.

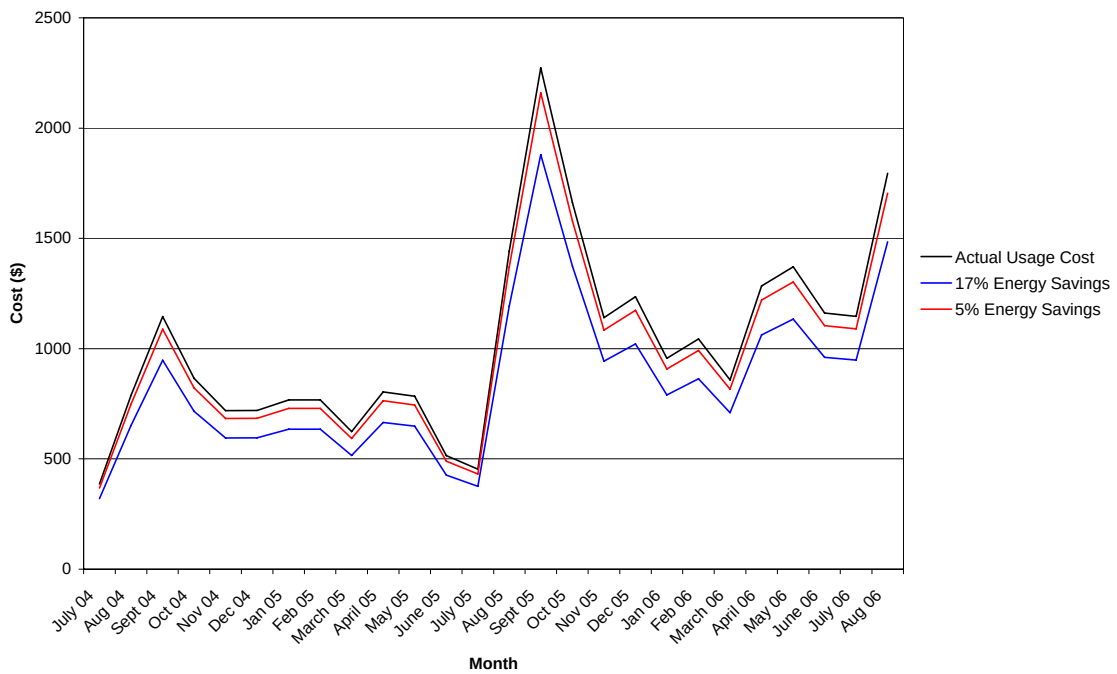


Figure 11. Potential Energy Savings over 2 Years

An additional finding shows an unplanned situation that occurred during a power outage at the school site. In Figures 12a, the first data logger had sensors located in the classroom space and the unconditioned attic space of the portable. The temperature reached approximately 130°F in the attic. Another data logger in the adjacent classroom of the same building was tracking classroom temperature as well as supply air duct

temperature. Figure 12b shows that the "insulated" supply duct reached a temperature of 115°F. This hot air has to be moved out when the compressor starts back up. In larger buildings, or numerous smaller buildings, this higher temperature will have to be overcome by increased run time of equipment, noting that the first air to be moved out of the duct into the space will be the stagnant, hot air in the supply duct.

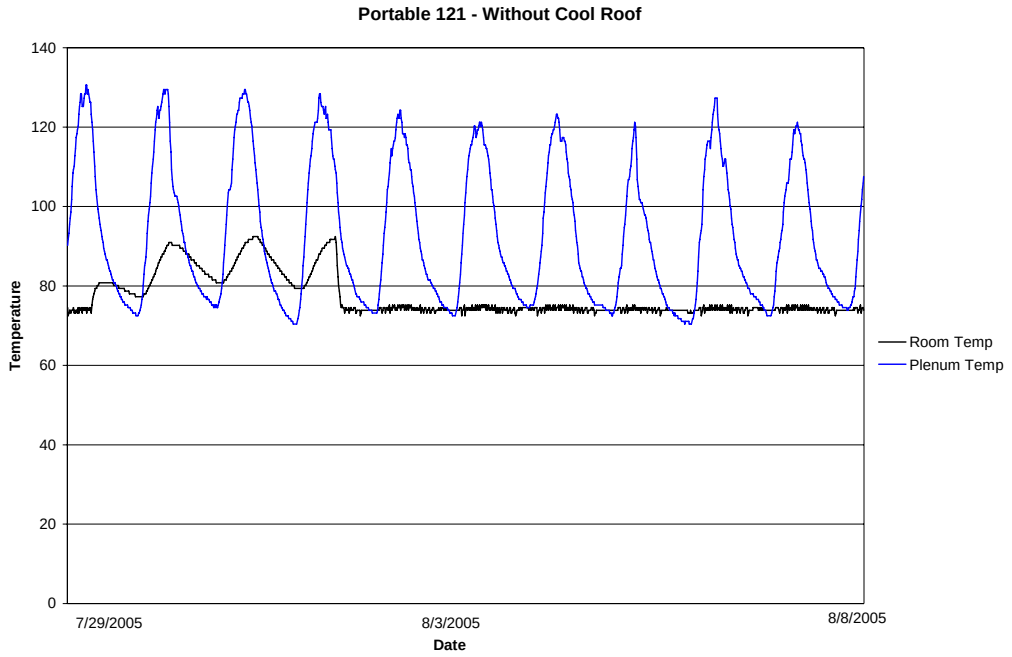


Figure 12a. Power Outage Response – Plenum vs. Room Temperature

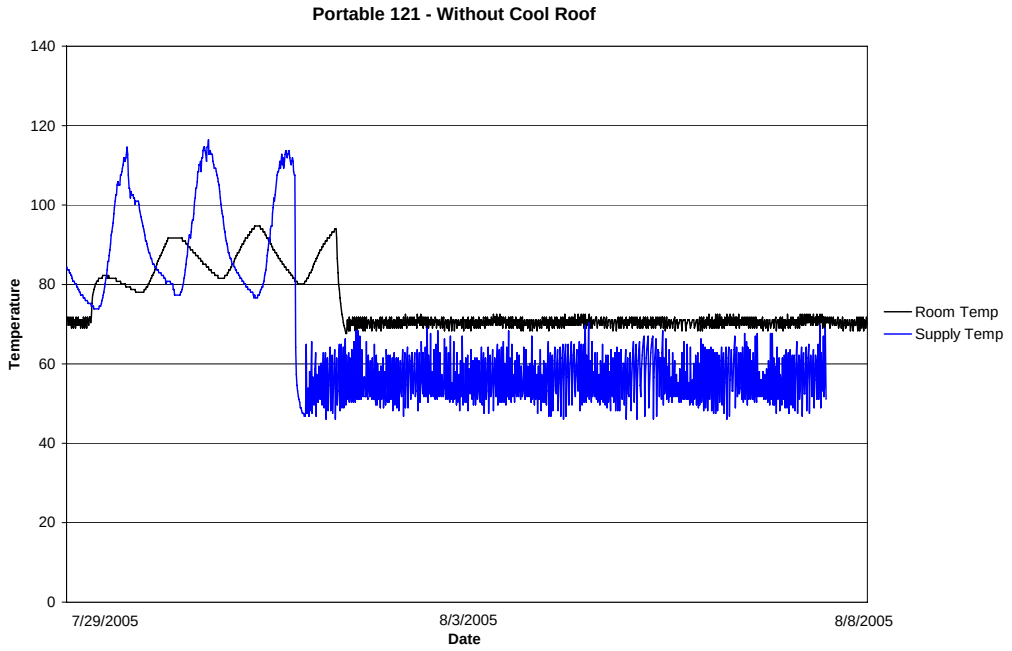


Figure 12b. Power Outage Response – Supply vs. Room Temperature

Conclusion

In conclusion, it is evident the cool roof does keep the plenum/attic temperatures lower in the cooling months. This reduction in temperature appears to reduce the work of the compressor which in turn reduces energy costs. The range of savings for a portable city based on this energy reduction can range from 0.4% to 17.4% depending on weather, equipment and set points. If you apply the 17.4% savings taken from the hottest month of the school year and apply it over the entire school year for 350 portables, the savings can be significant as shown in the graph below (Figure 13). The potential total savings for this year is $94,311 for 350 portables. This cost was extrapolated from the utility costs received from the school district for the year. Many factors contribute to the payback. These include the cost for the coating, the total square footage for all portables, number of locations of the portables, condition of the portables and utility rates for the area. At a relatively low cost to apply, averaging $0.65-0.85 per square foot, the payback can range from 3.6-4.7 years for the San Antonio area. This estimate is for 350 portables at 1,500 square feet each.

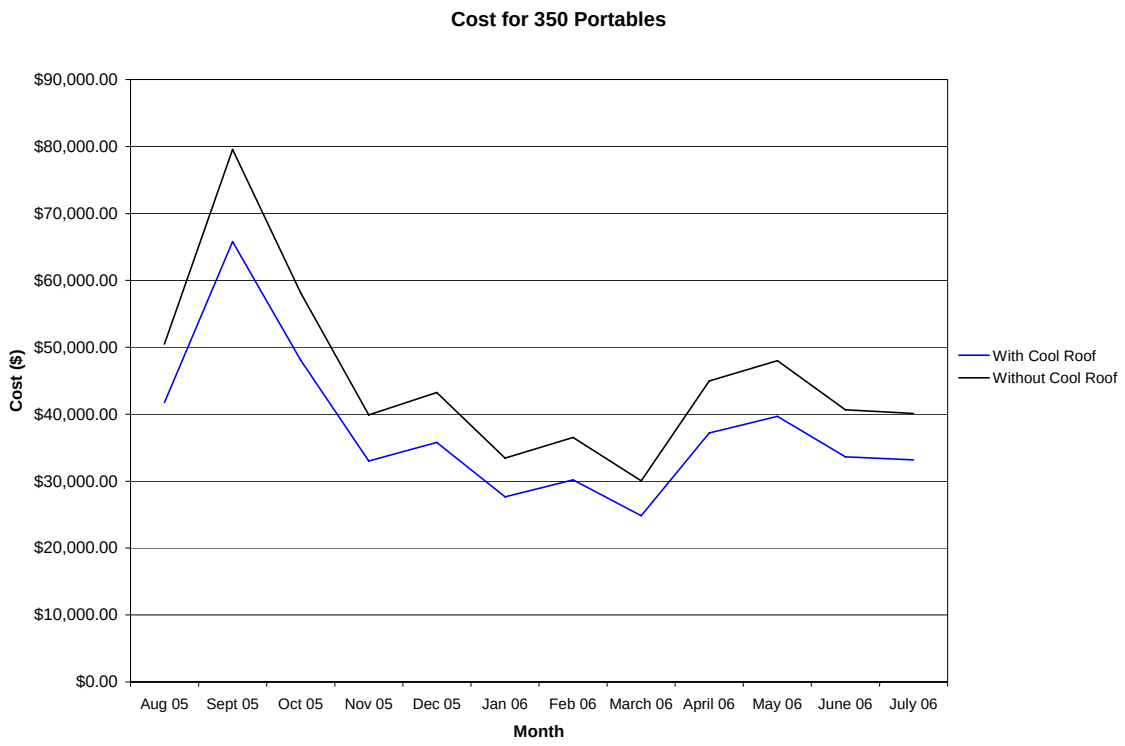


Figure 13. Cost Reduction over a School Year

Since the utility rates vary in the state of Texas, figure 14 demonstrates the payback for a range of utility rates. San Antonio has a lower utility rate than other areas in Texas. The Laredo-Corpus Christi area pays $0.127-0.161 per kWh, Houston area pays $0.135-0.157 per kWh and Dallas-Fort Worth pays $0.128-0.145 per kWh.

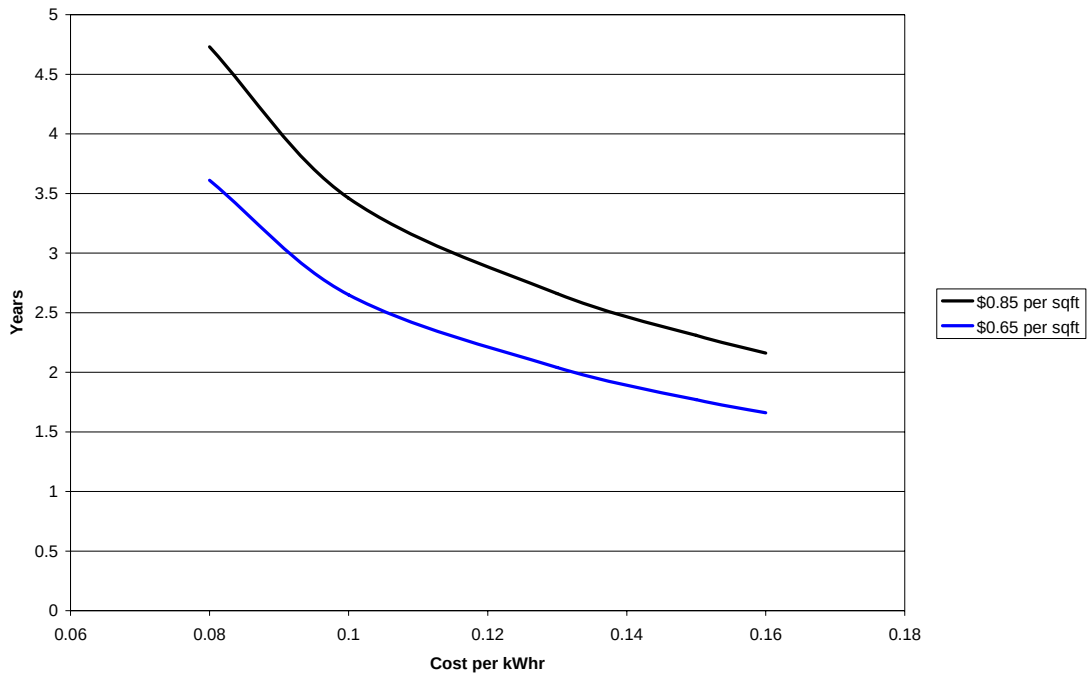
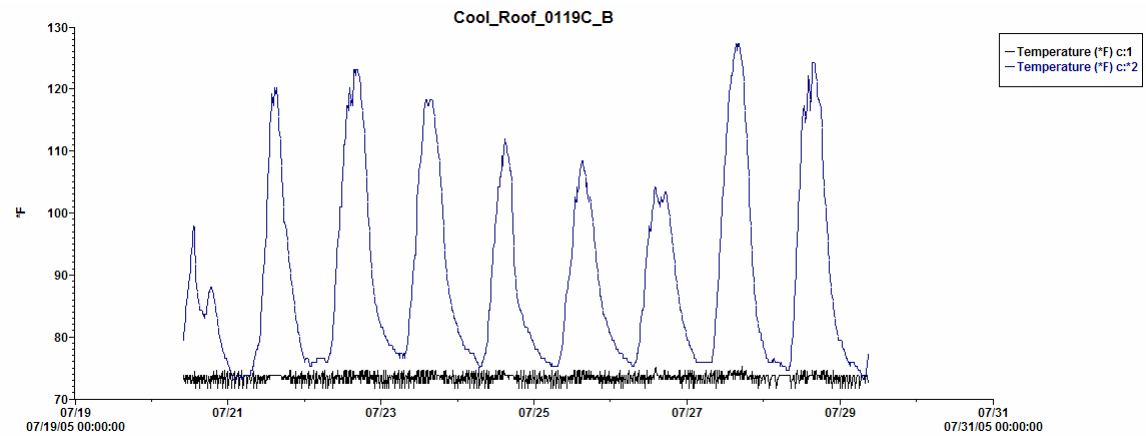


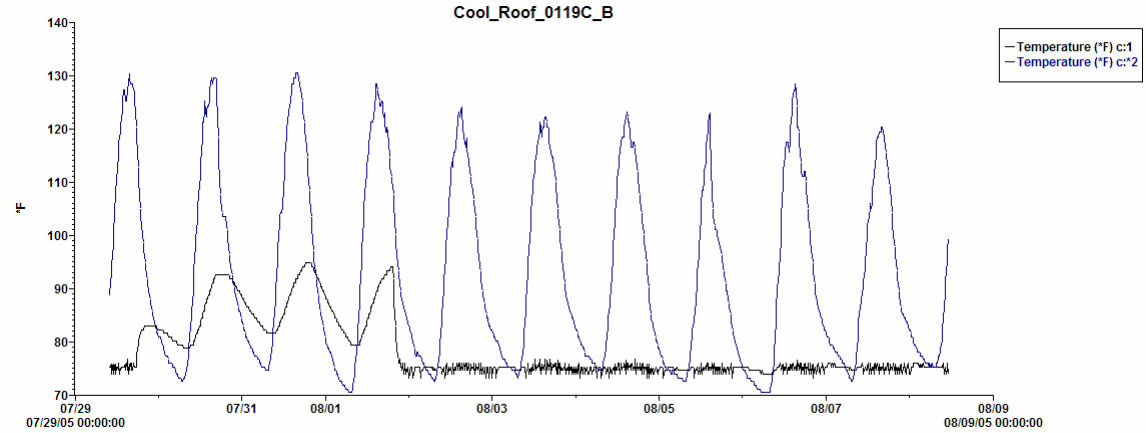
Figure 14. Payback for Varying Utility Rates in Texas

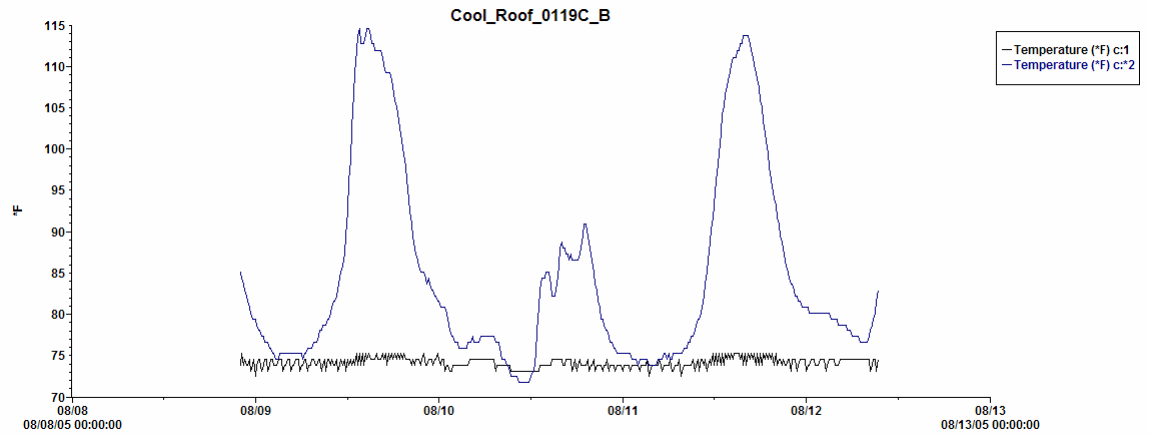
In this study, only the ceiling temperatures was taken into account for heat transfer since it was the roof that was addressed with the Microteja® coating. Other parameters to look at for future energy efficiency in portable buildings are the walls, windows and doors. The surface area on the portable buildings is small in comparison to a gym or regular classroom which energy reduction would be more significant. Since the start of this study, cool roof technology has advanced to include application to a variety of roofing materials.

Appendix A – Data Logger Graphs

The data loggers recorded data over the course of this study. This appendix contains the actual data graphs from the Onset Computers Inc. software. The graphs are in order of portable and date. Portables 119 and 121 do not have the cool roof coating while portables 120 and 122 have the cool roof coating applied. In the legend on the graphs, temperature c*1 is the room temperature and temperature c*2 is the plenum/attic temperature.



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Temperature (°F) c:*2
°F
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110
105
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95
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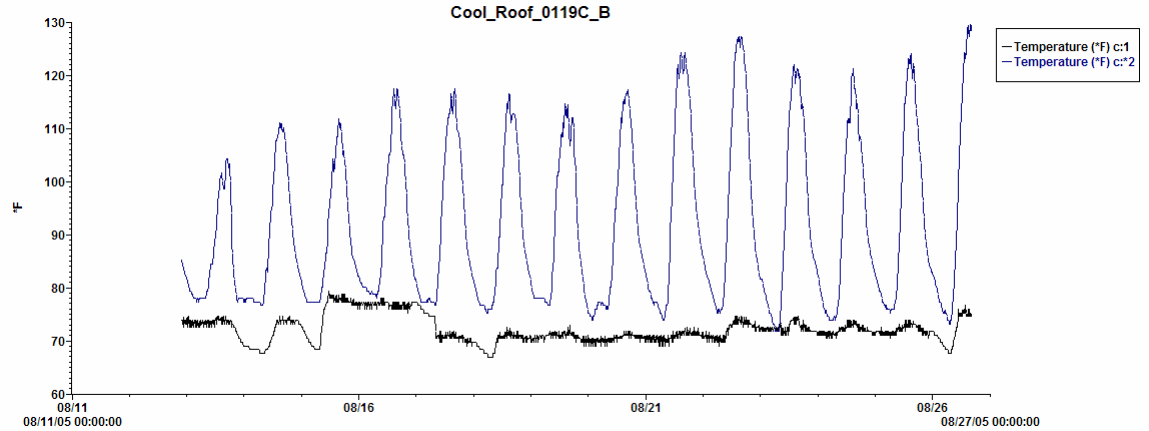
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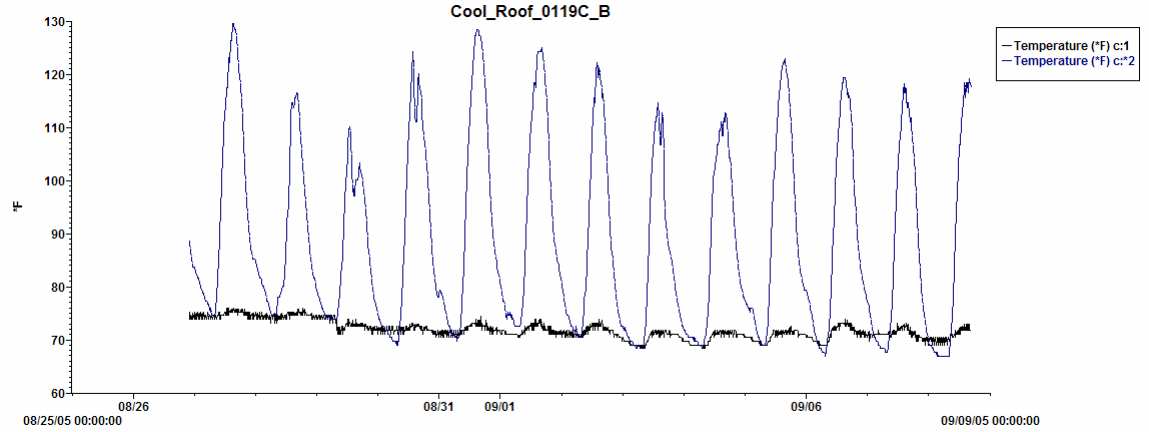
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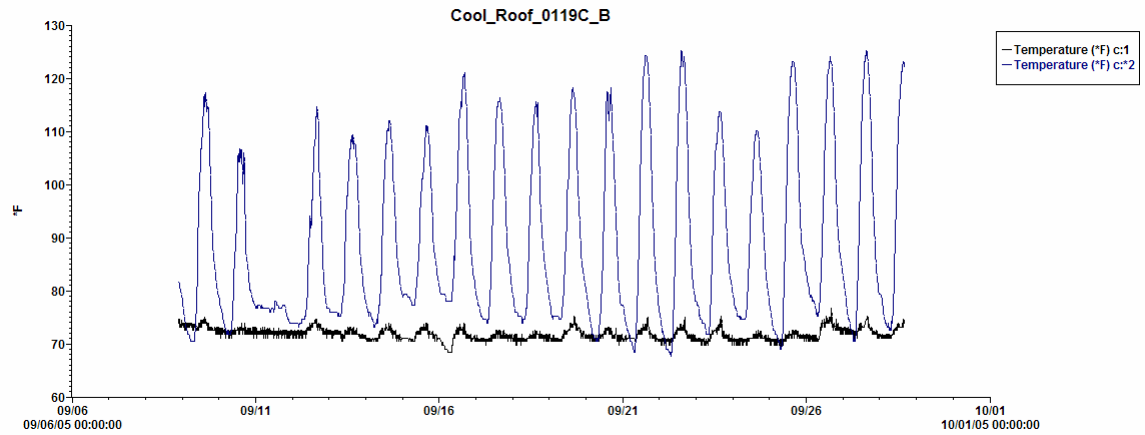
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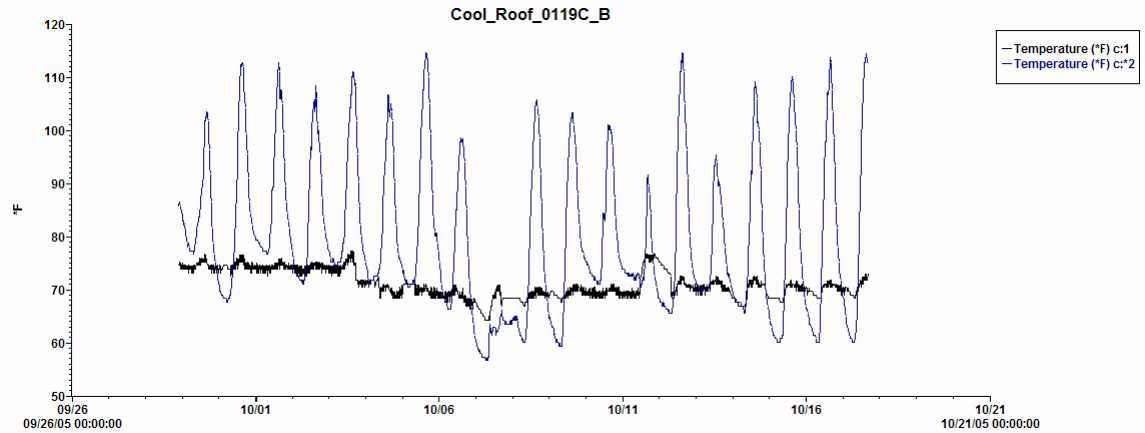
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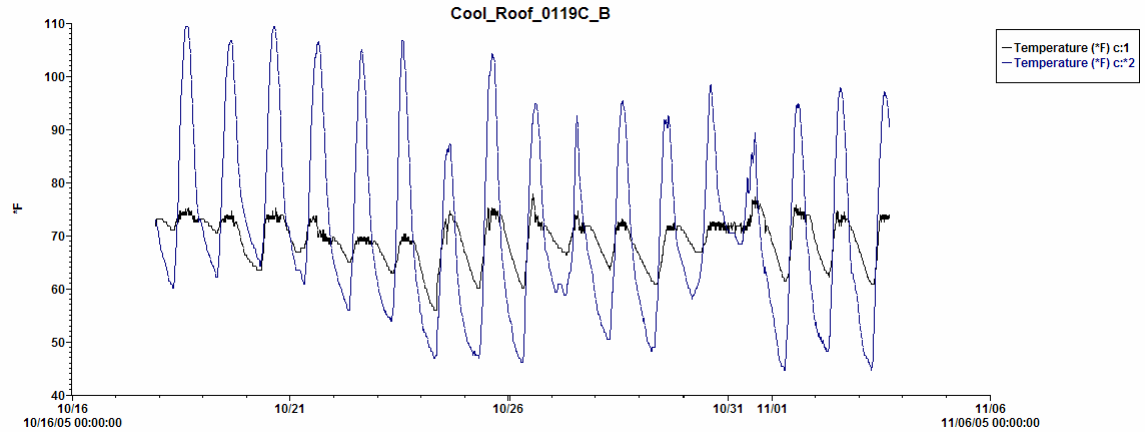
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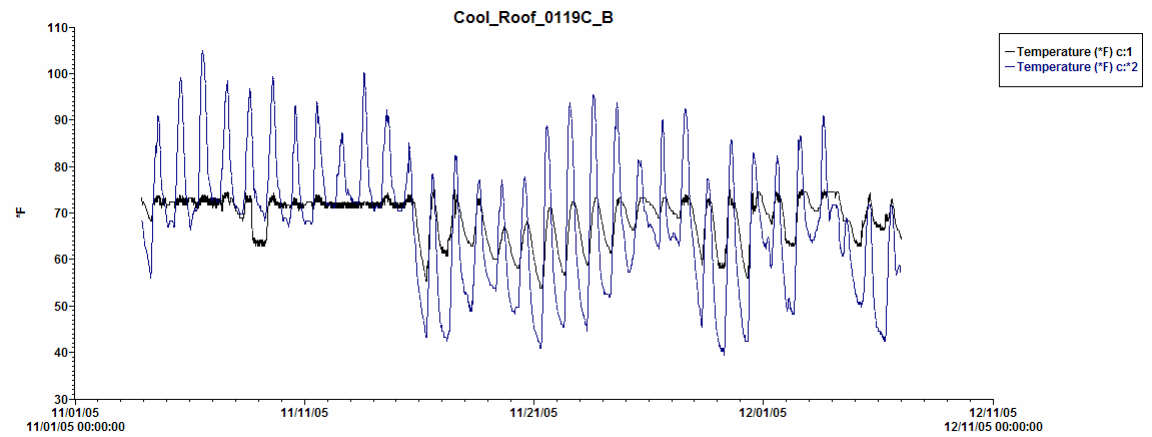
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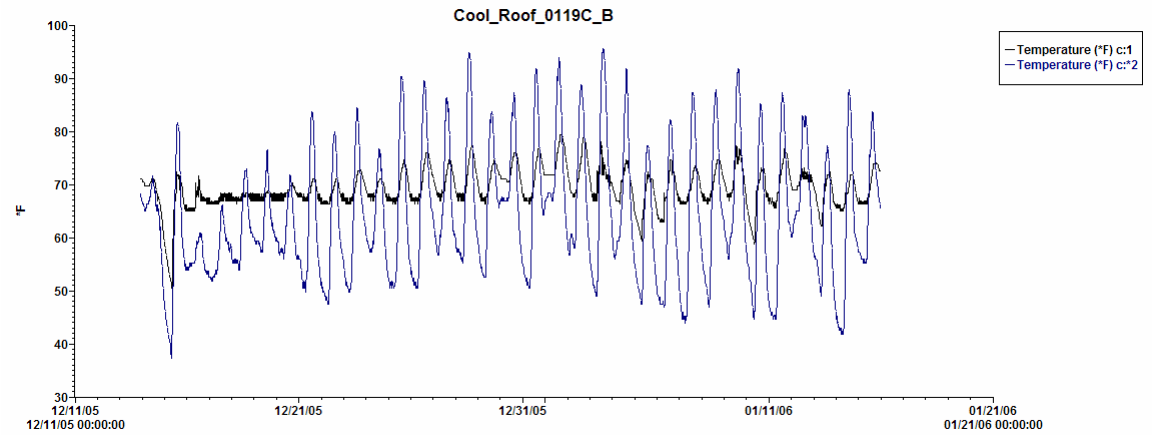
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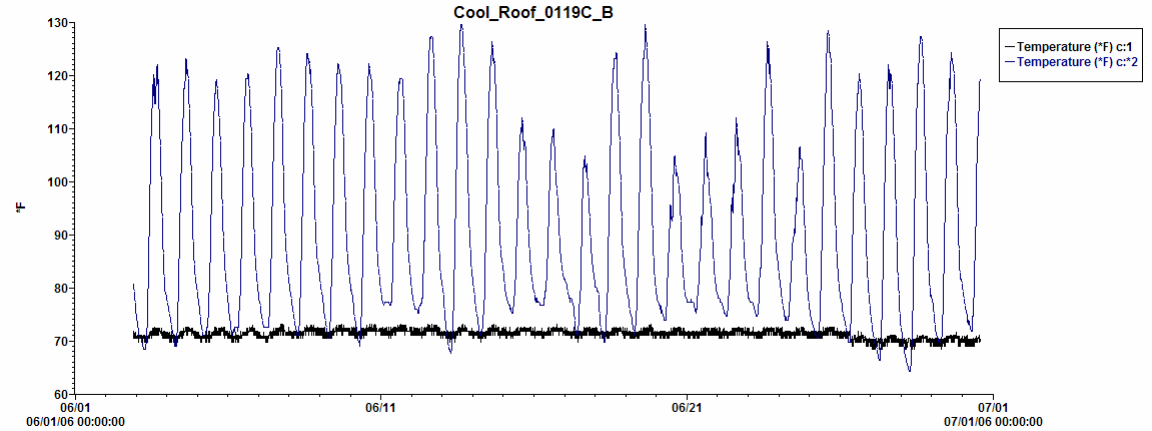
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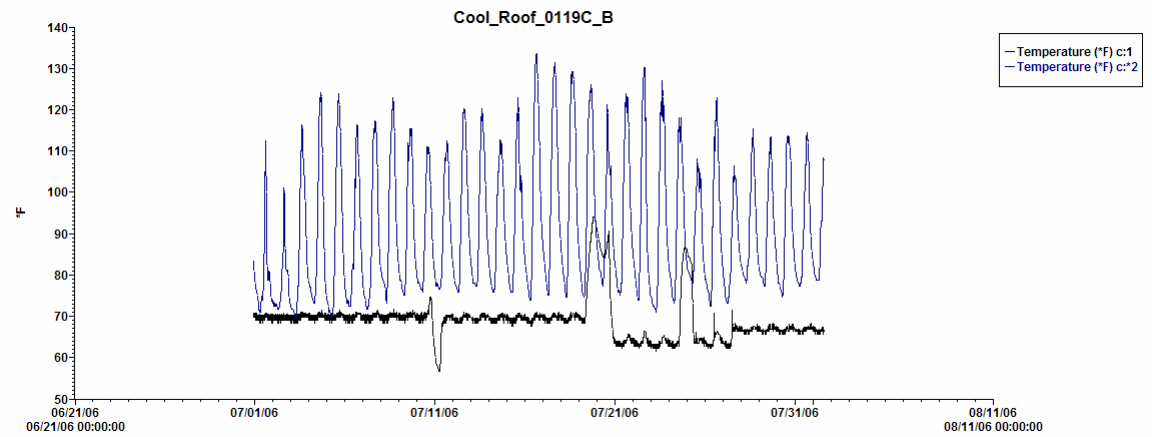
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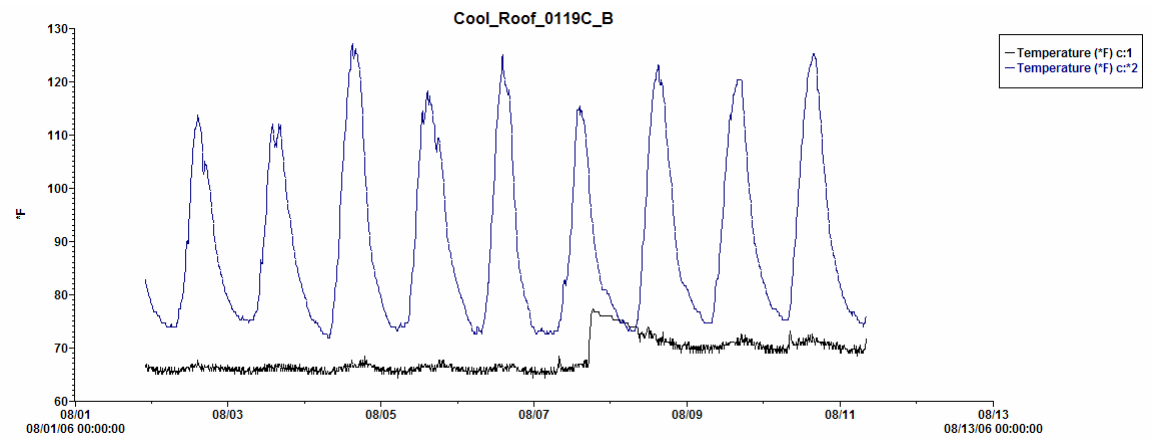
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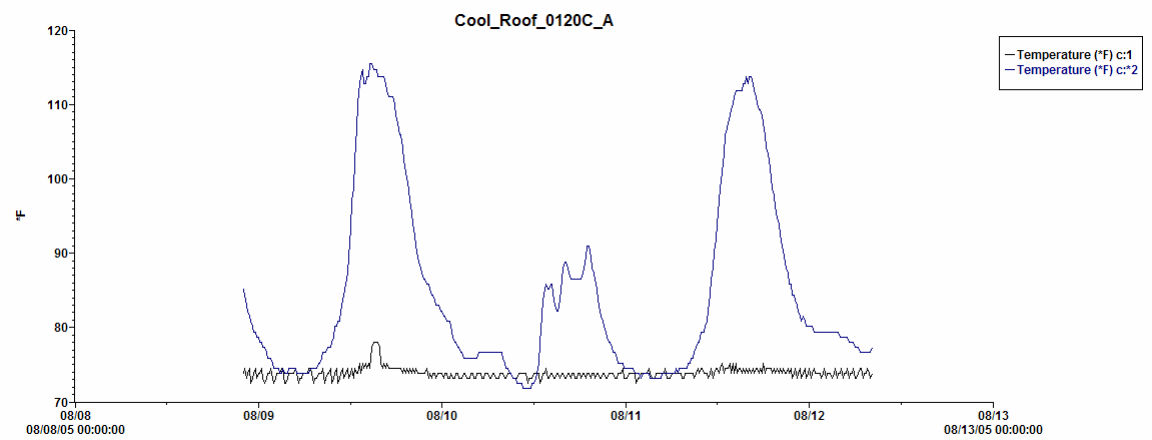
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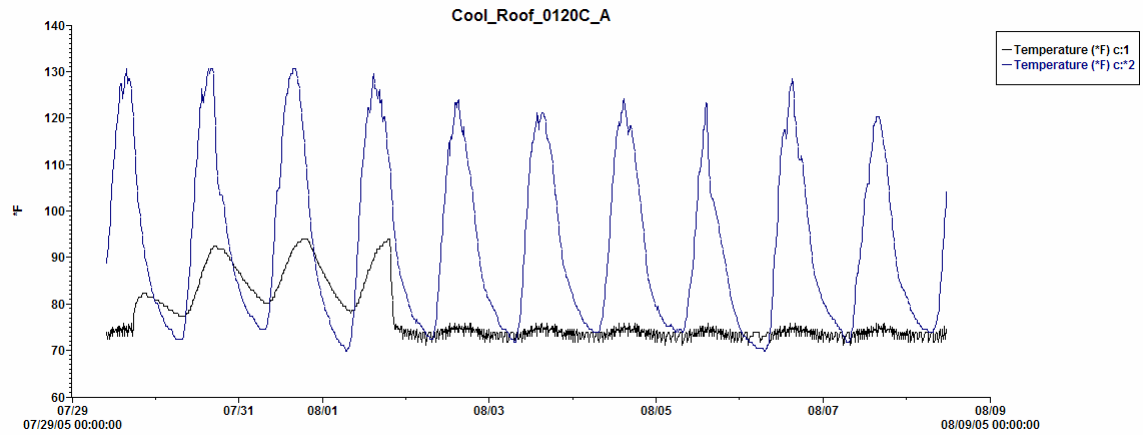
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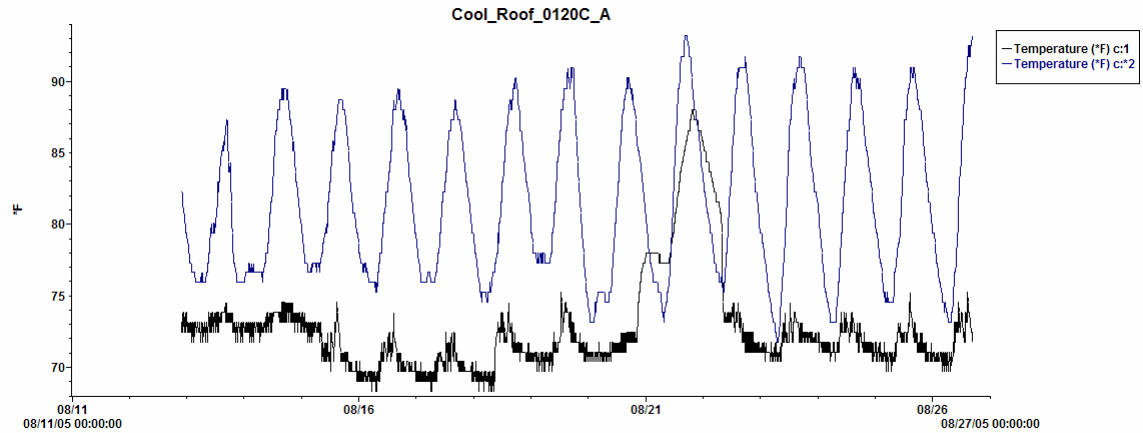
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Temperature (°F) c:*2
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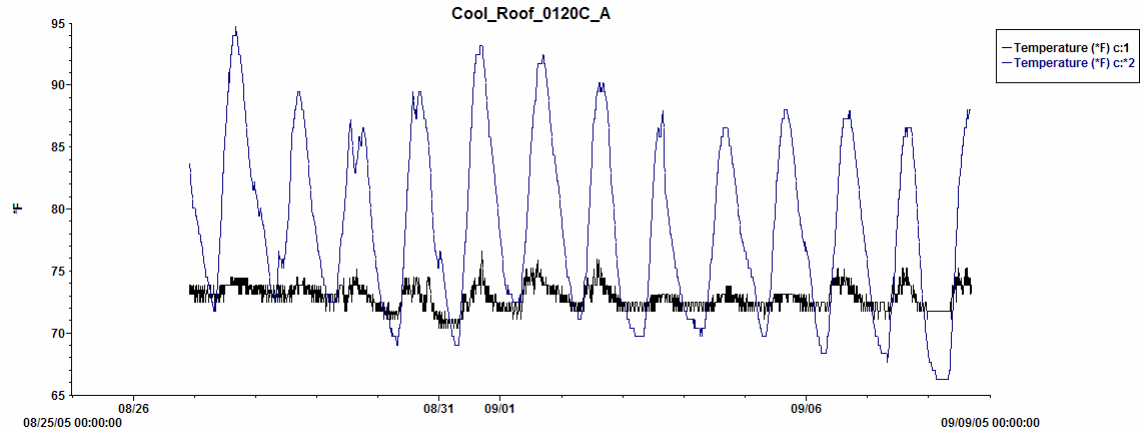
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Temperature (°F) c:*2
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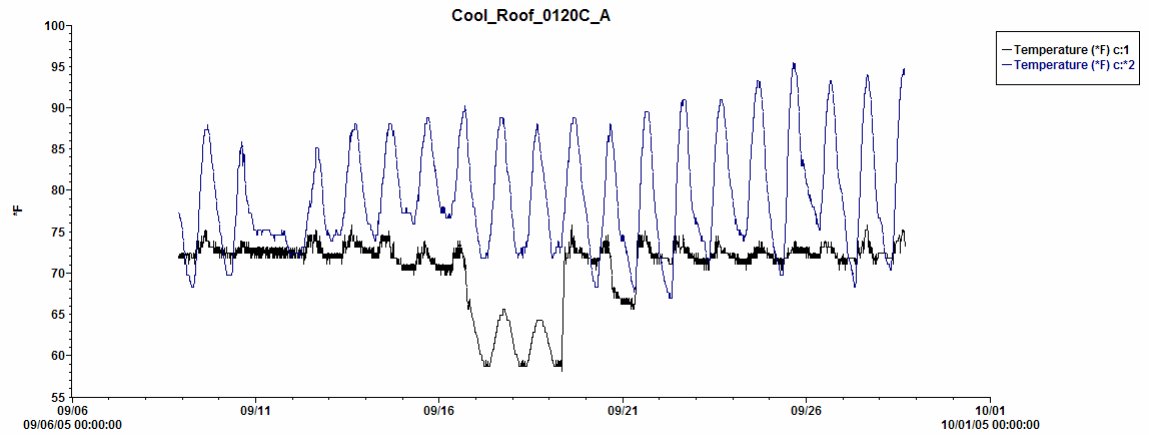
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Temperature (°F) c:*2
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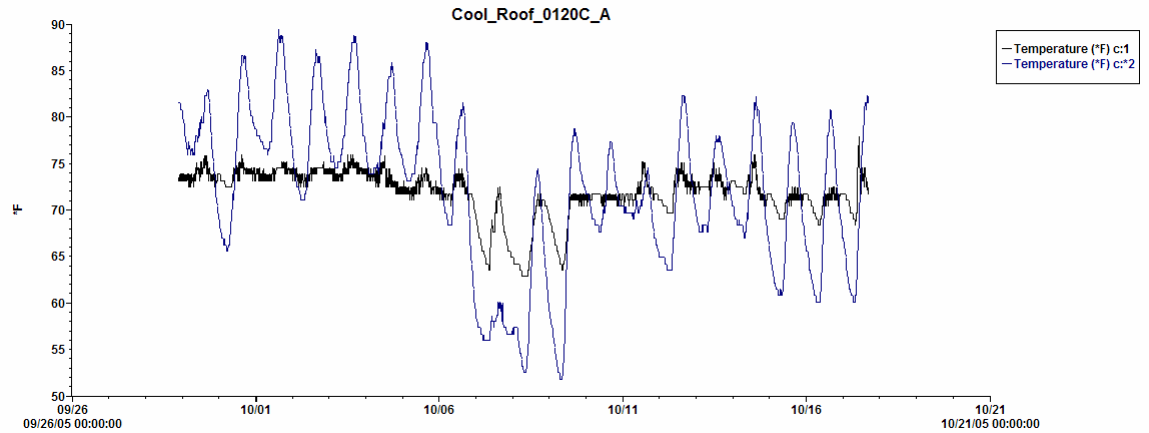
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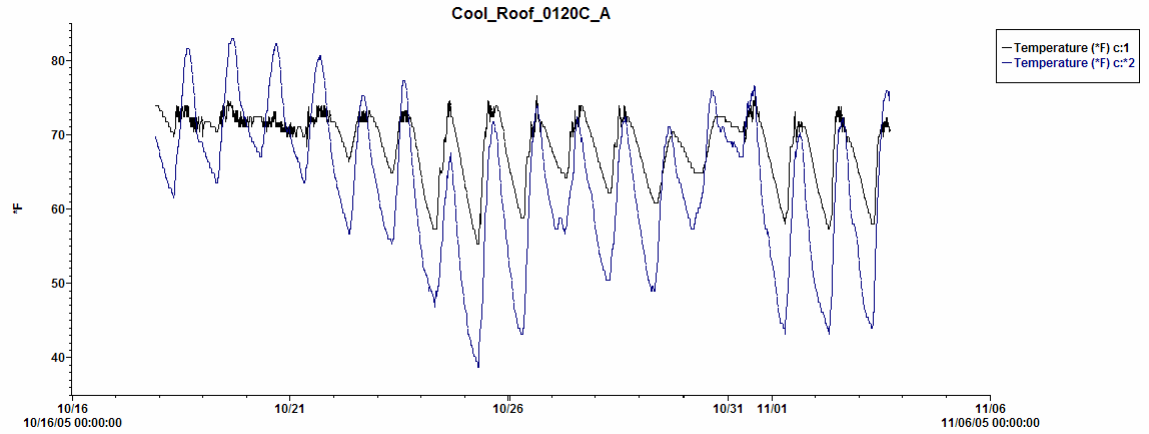
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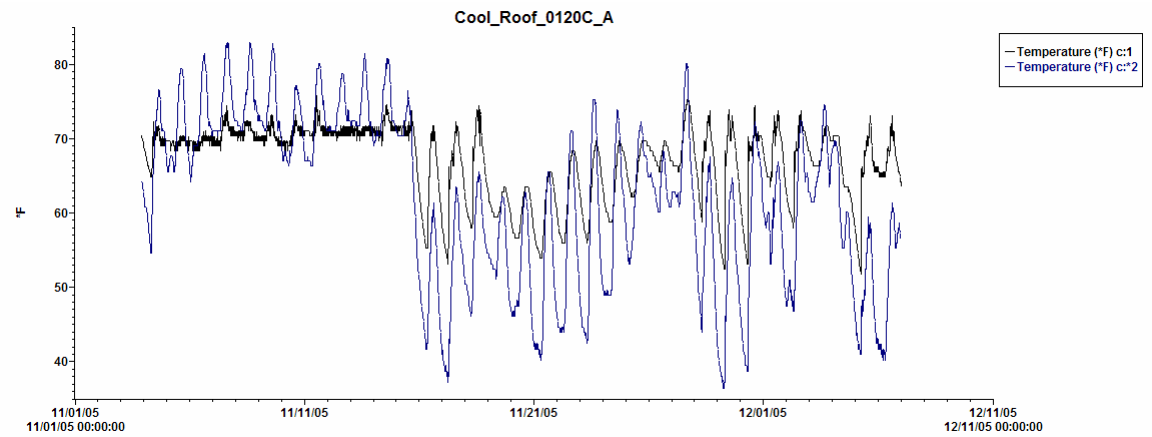
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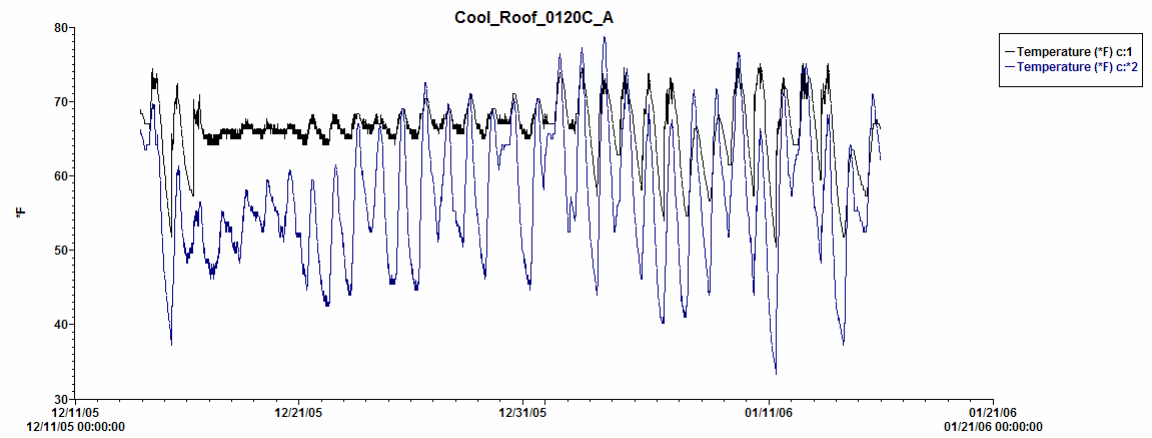
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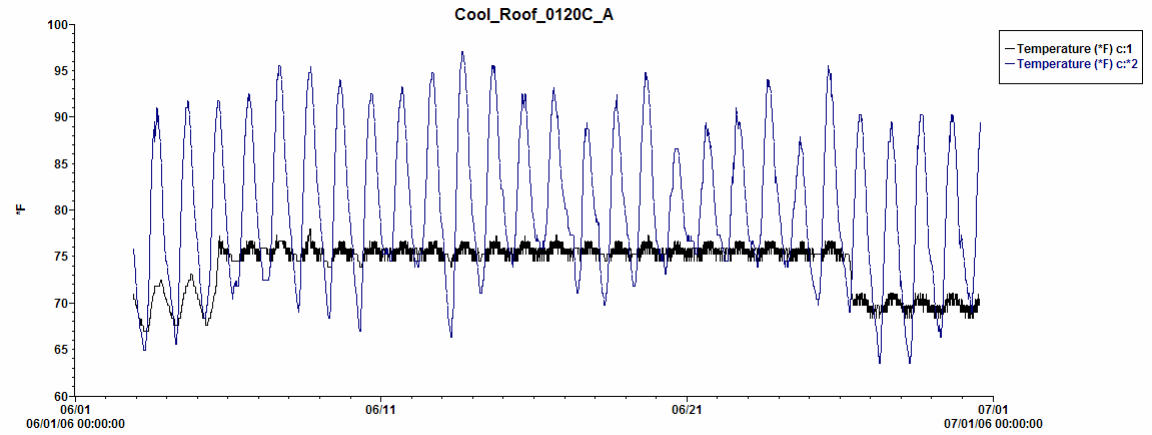
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Temperature (°F) c:1
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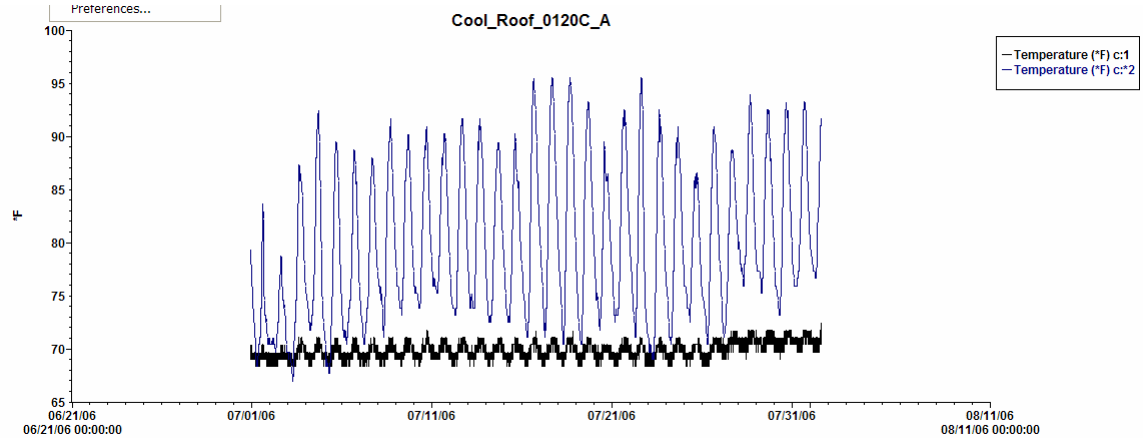
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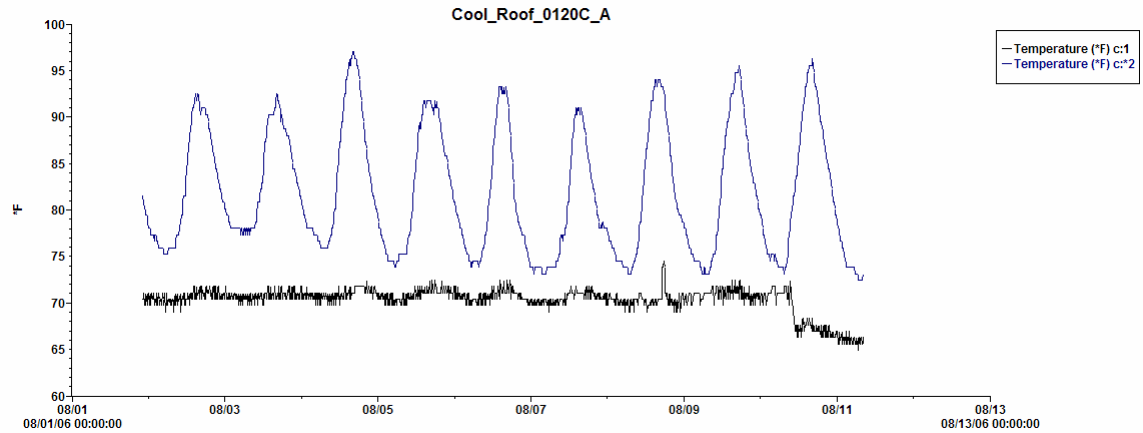
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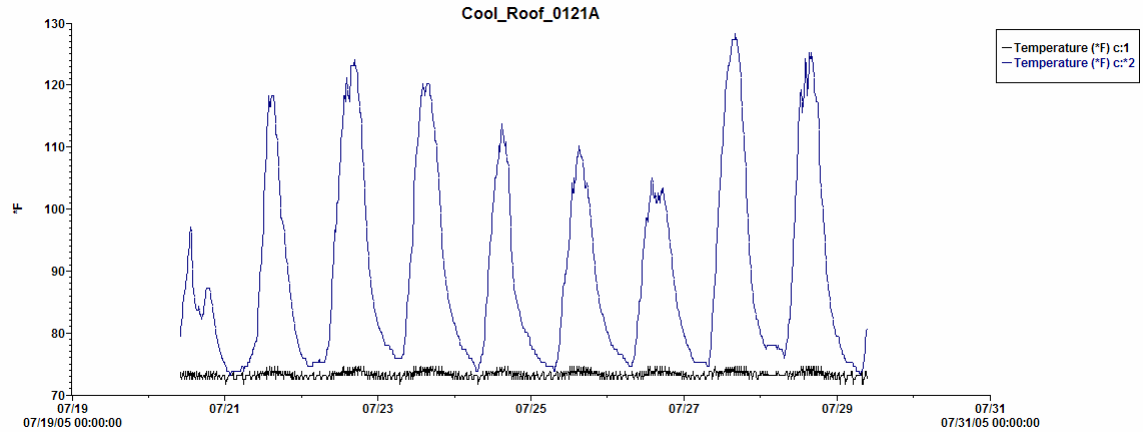
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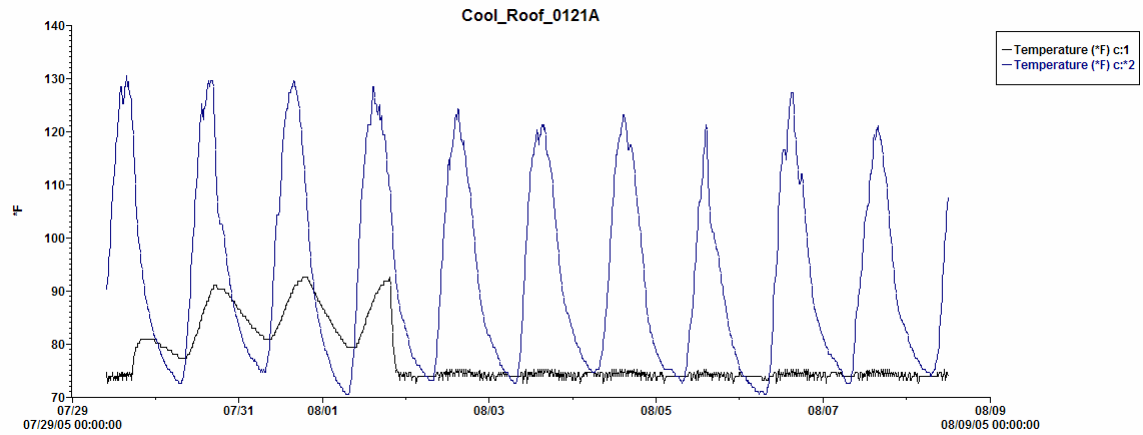
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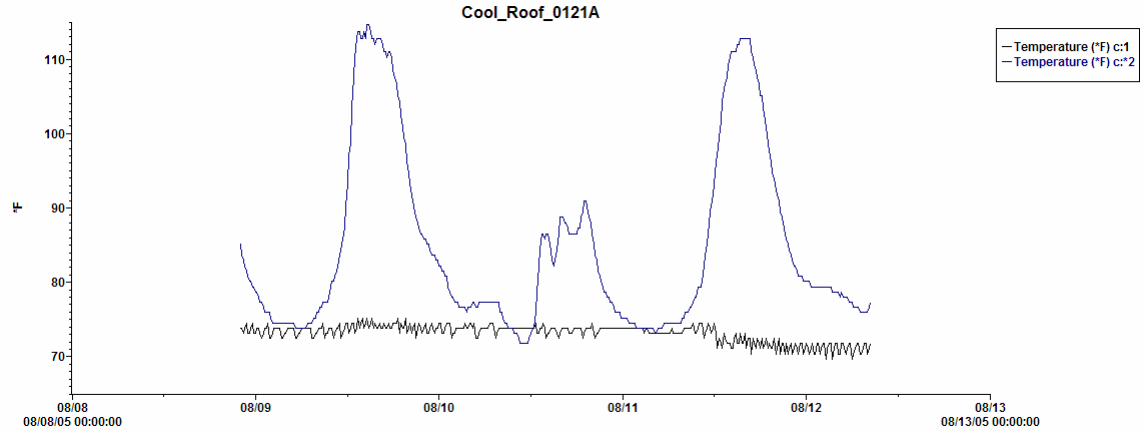
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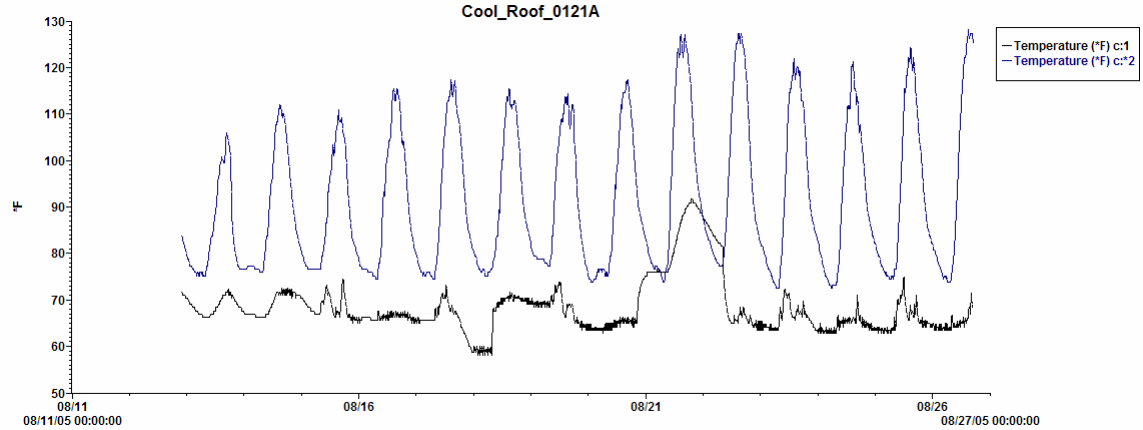
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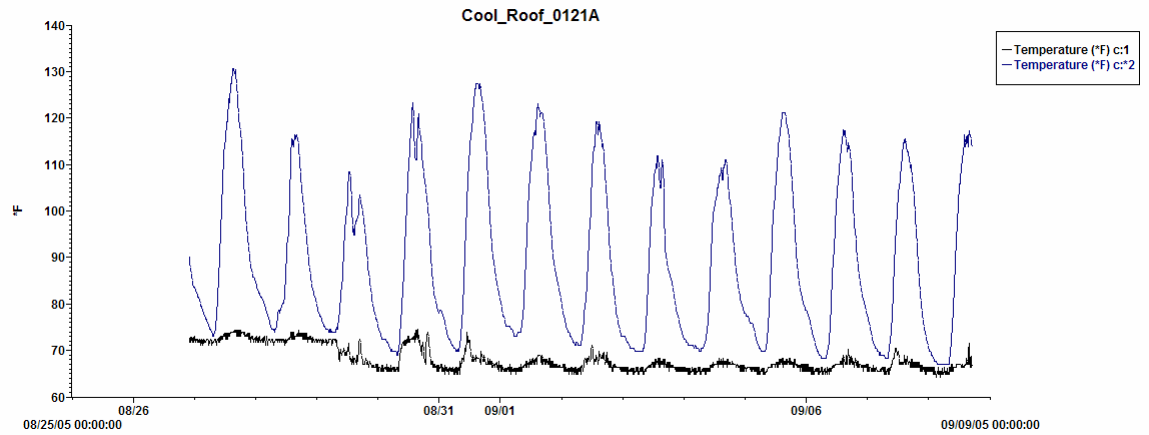
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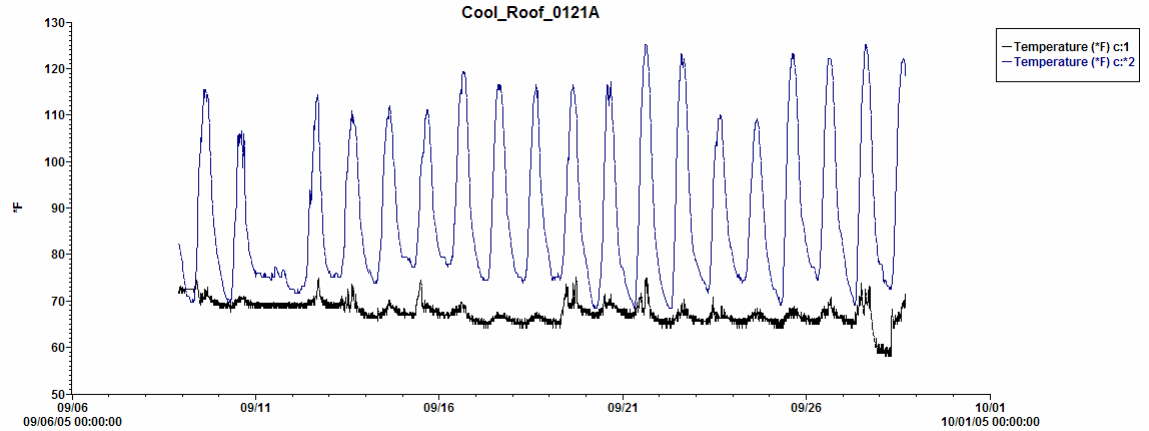
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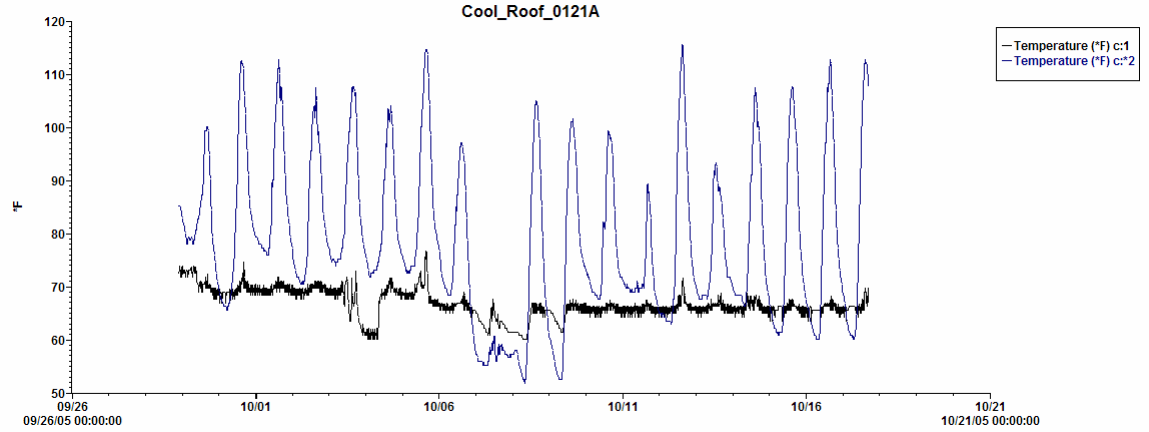
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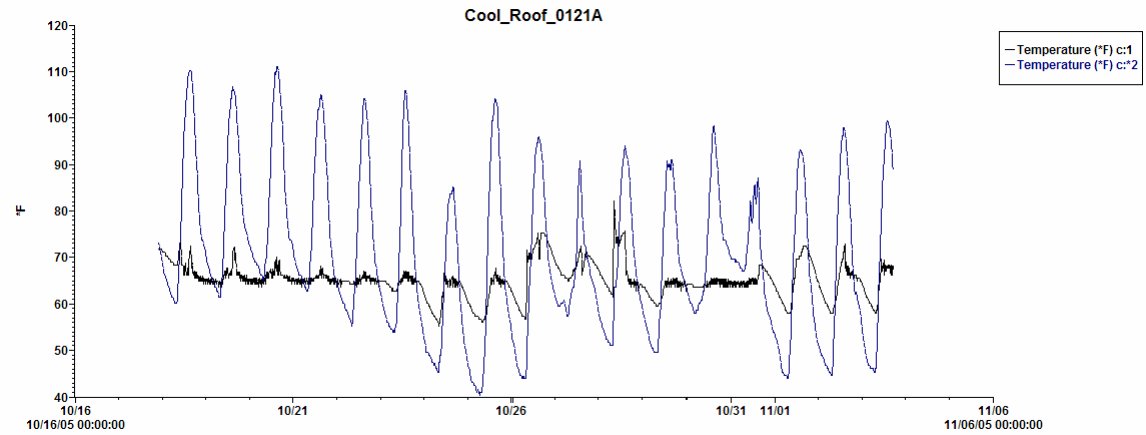
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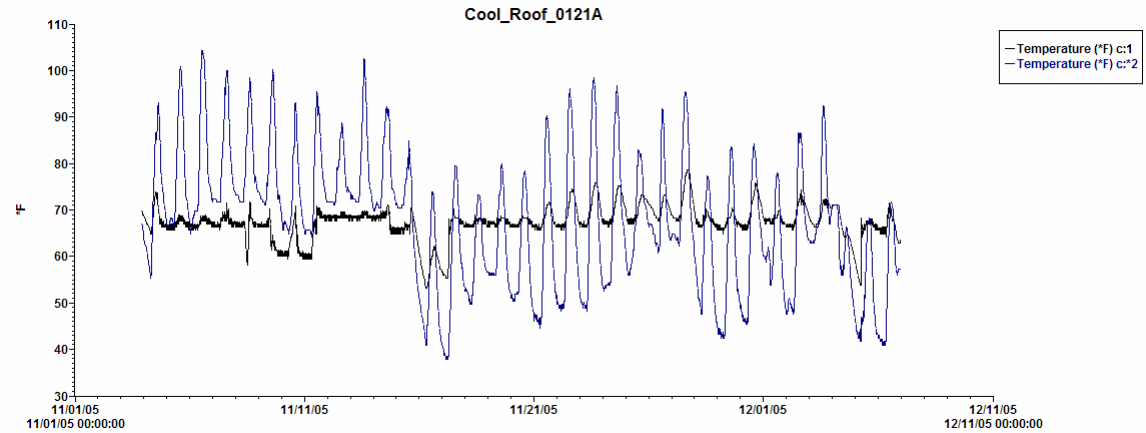
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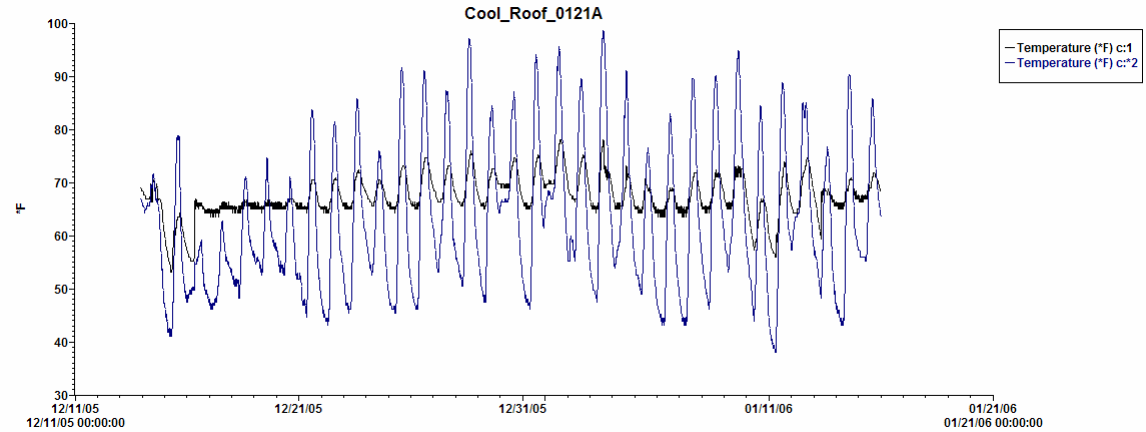
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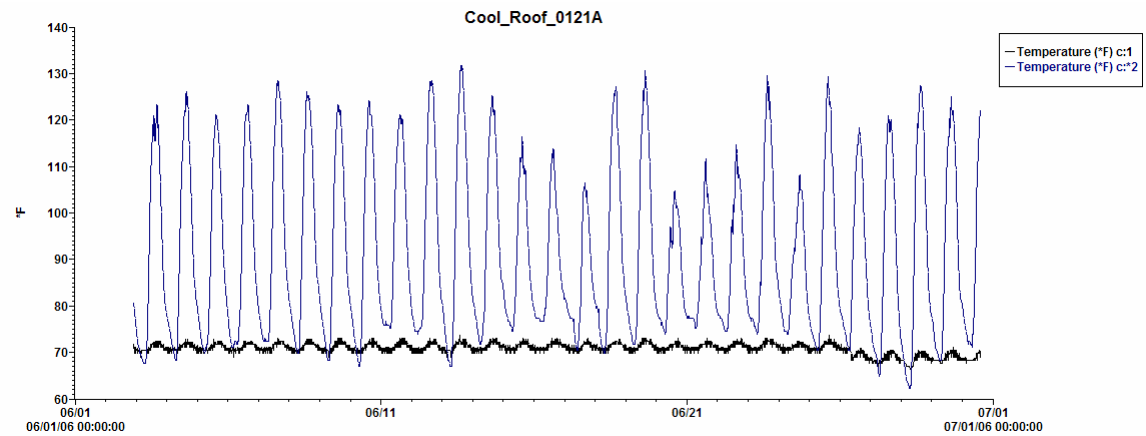
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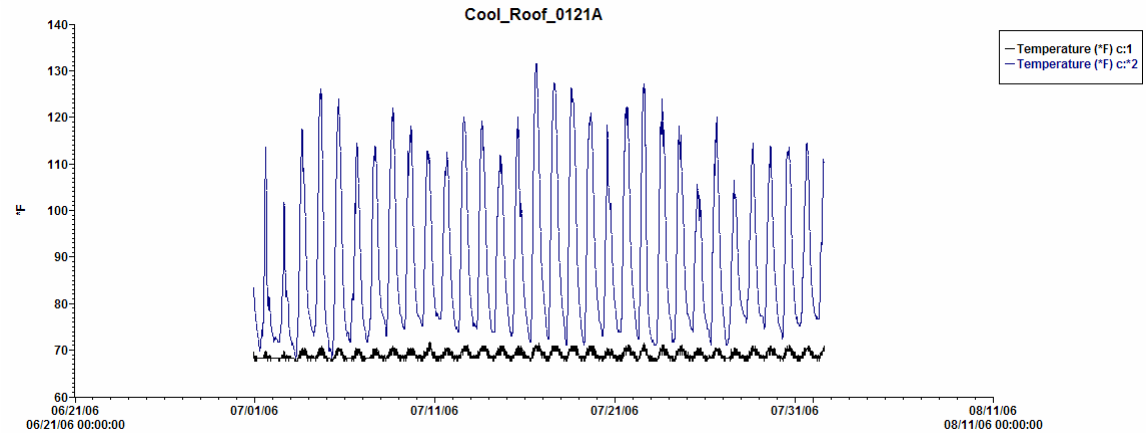
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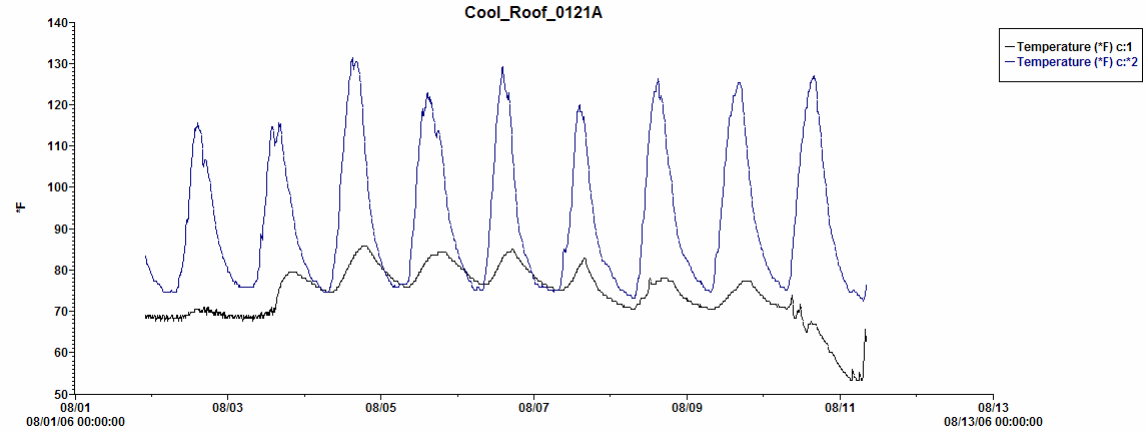
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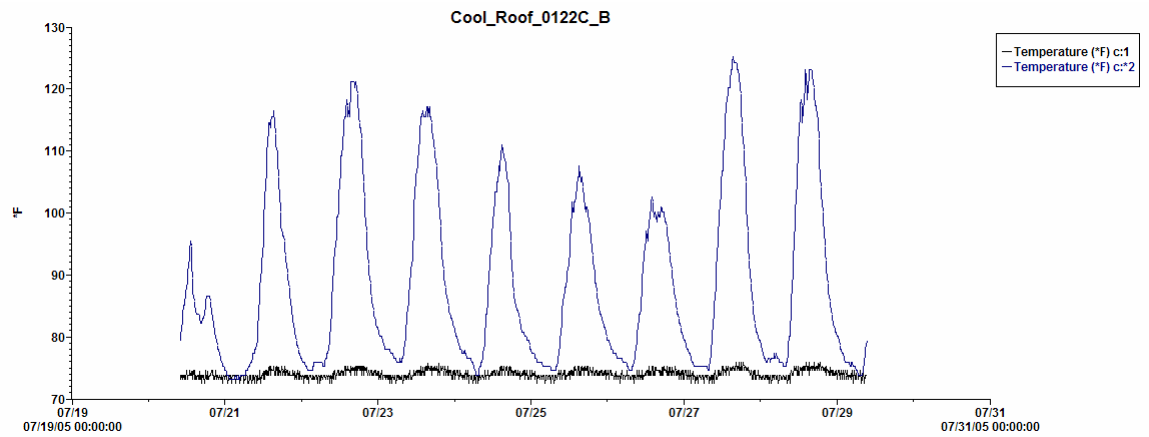
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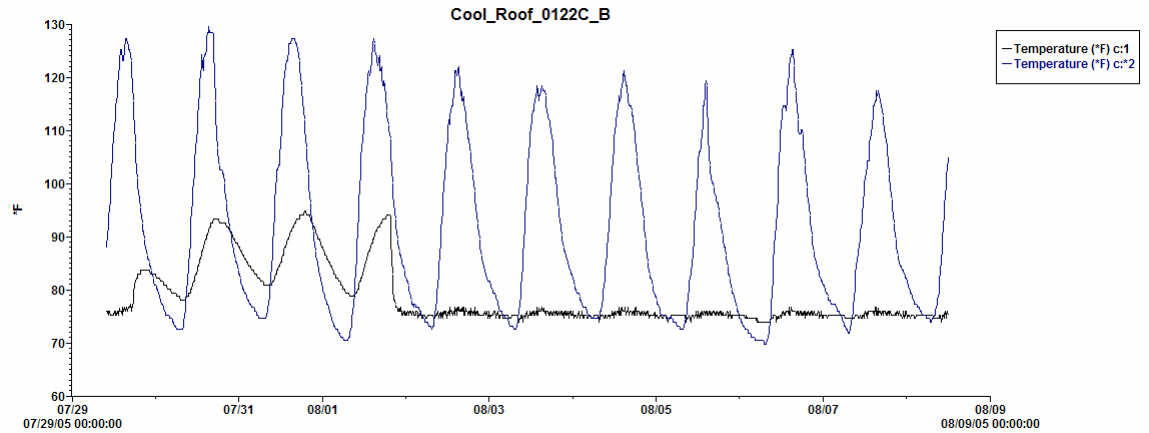
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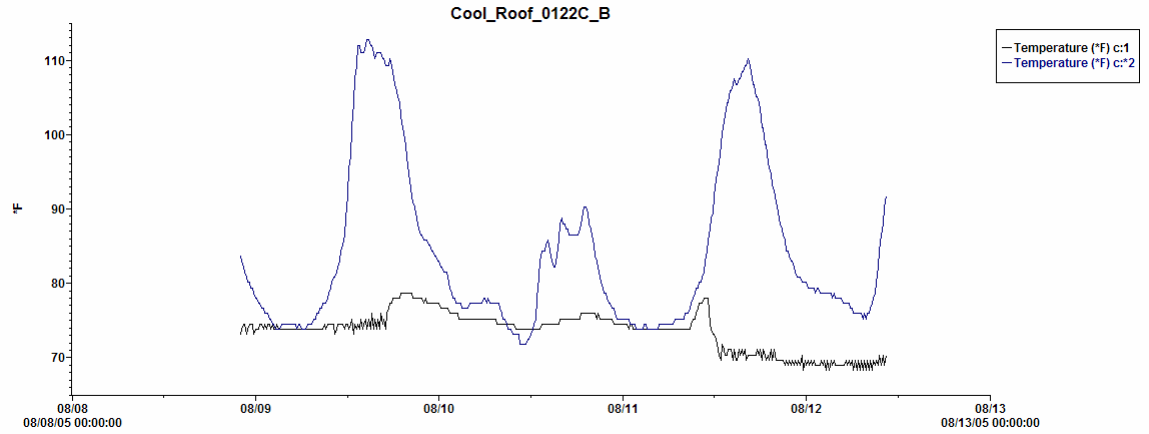
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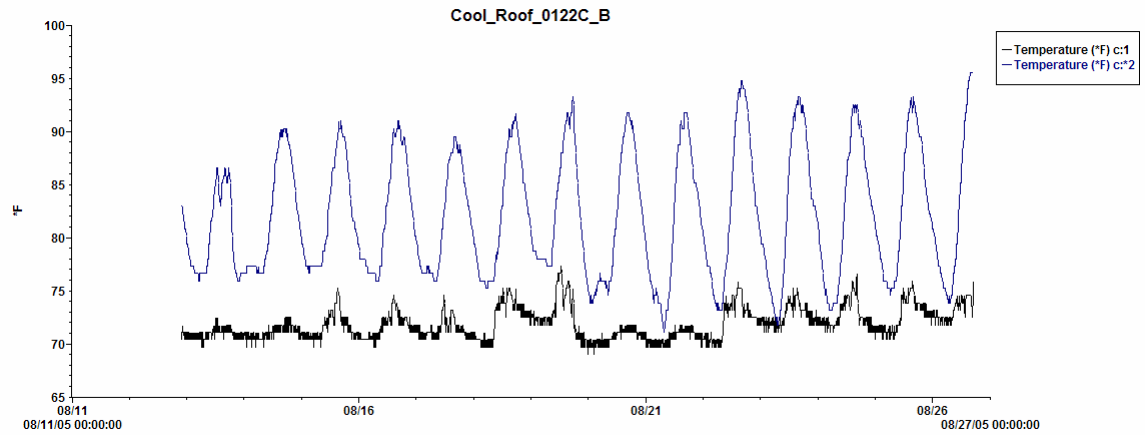
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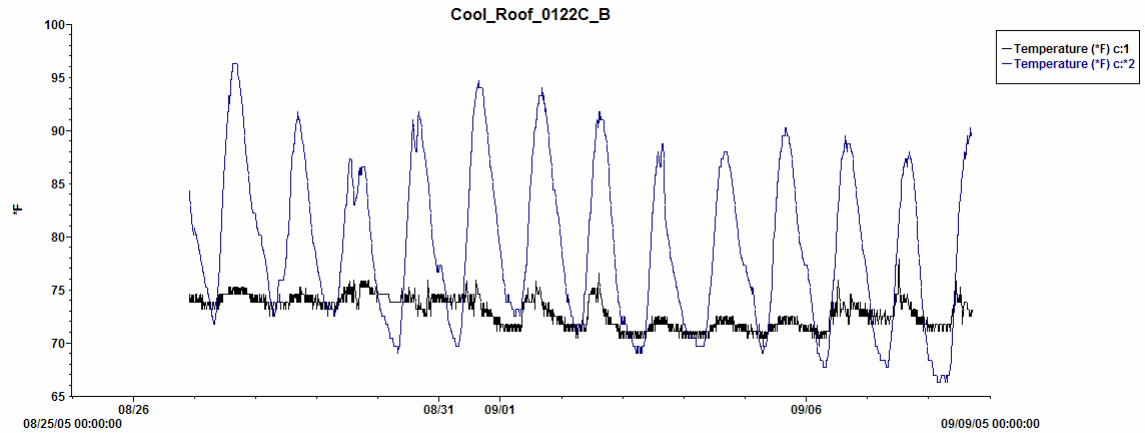
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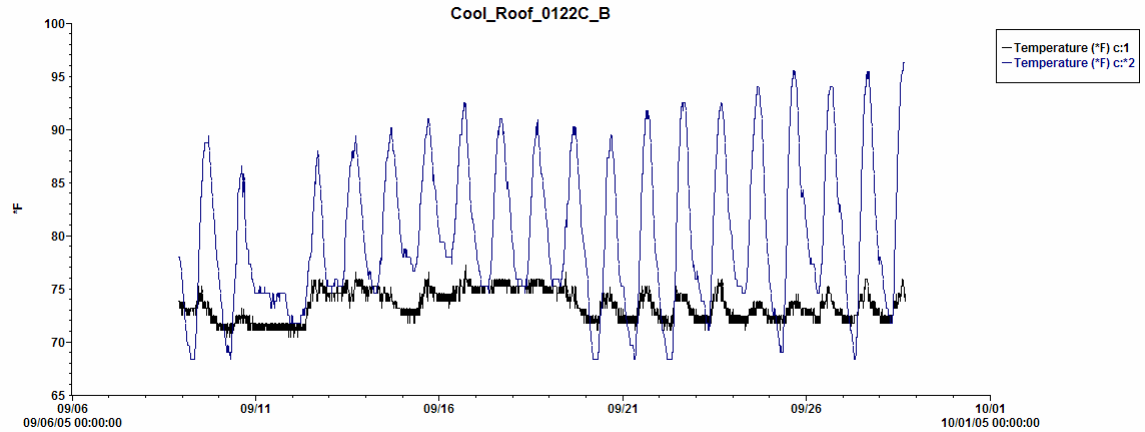
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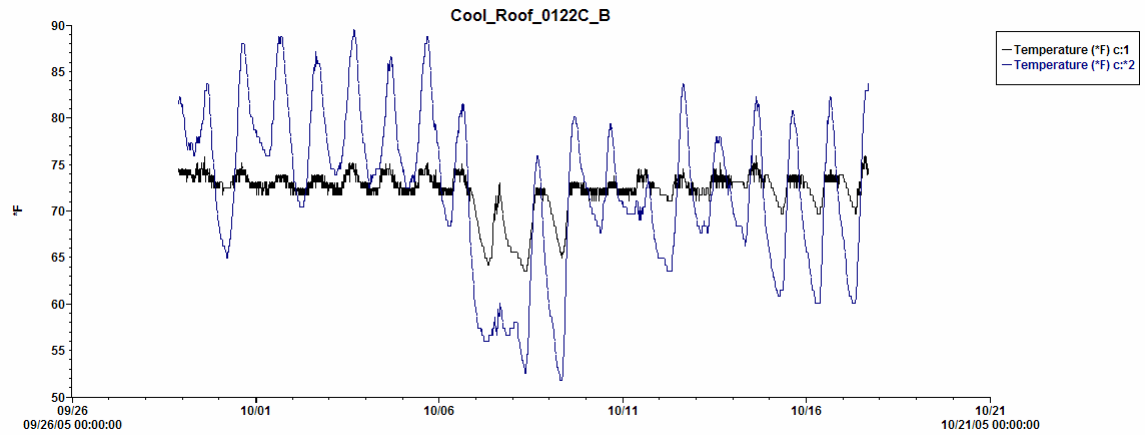
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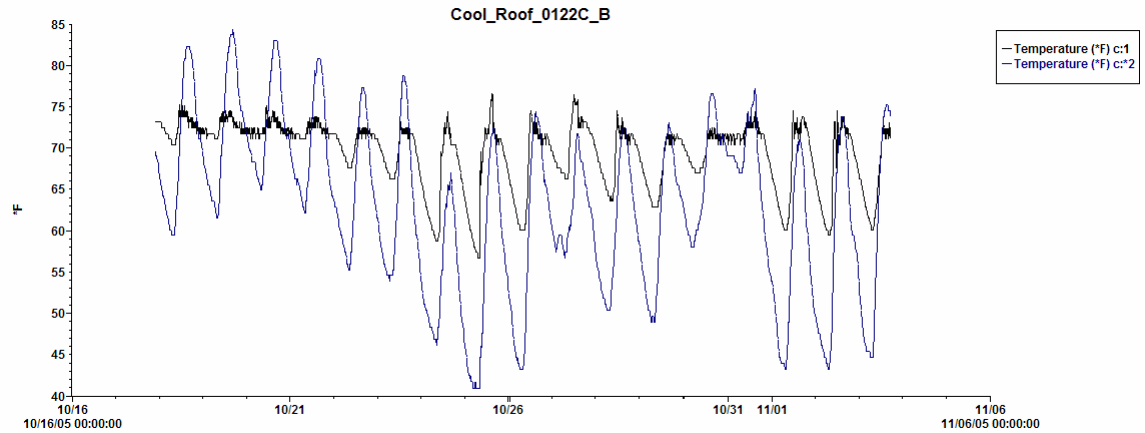
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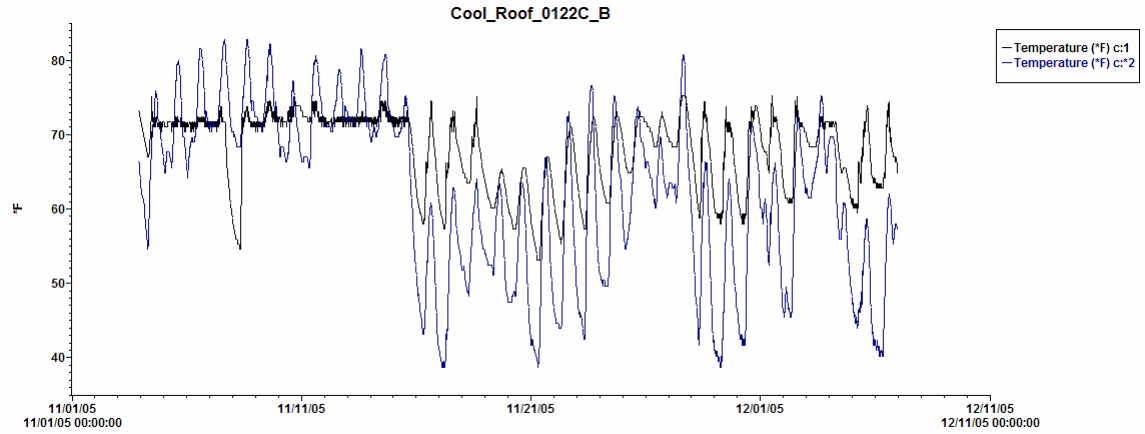
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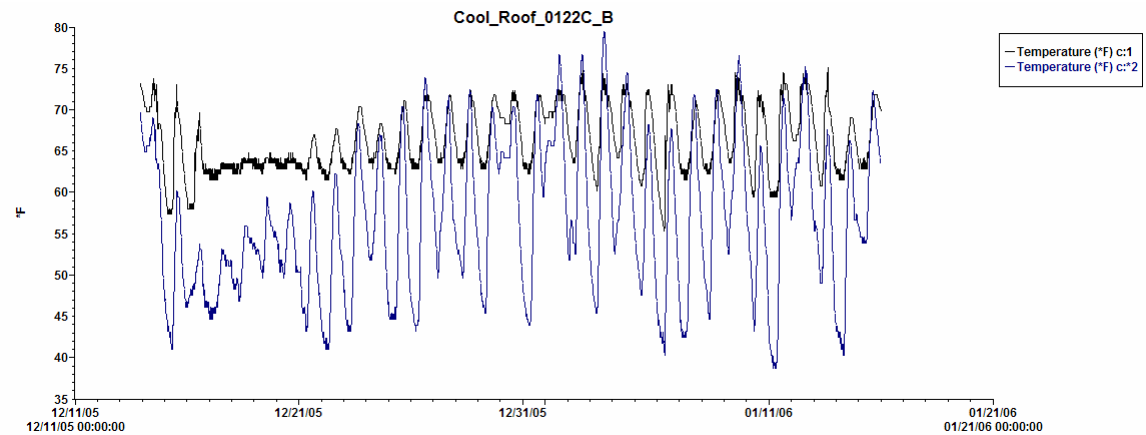
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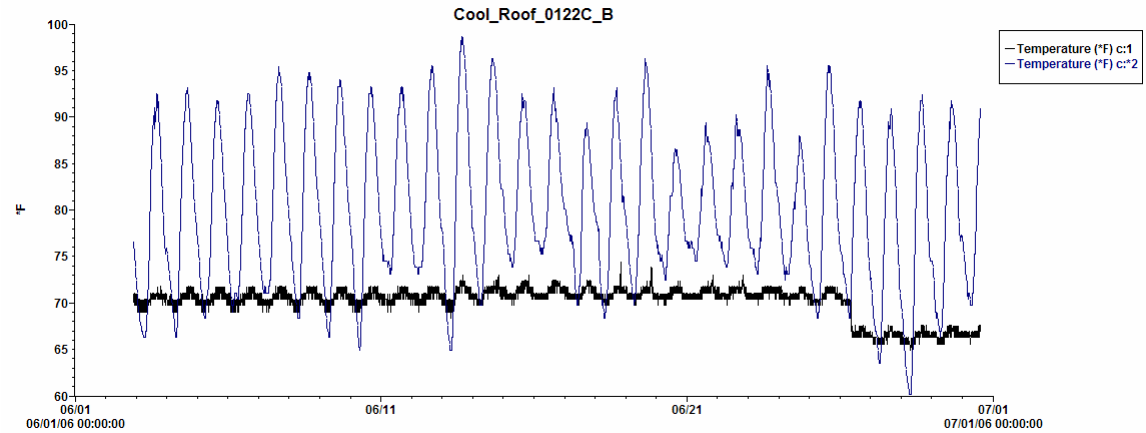
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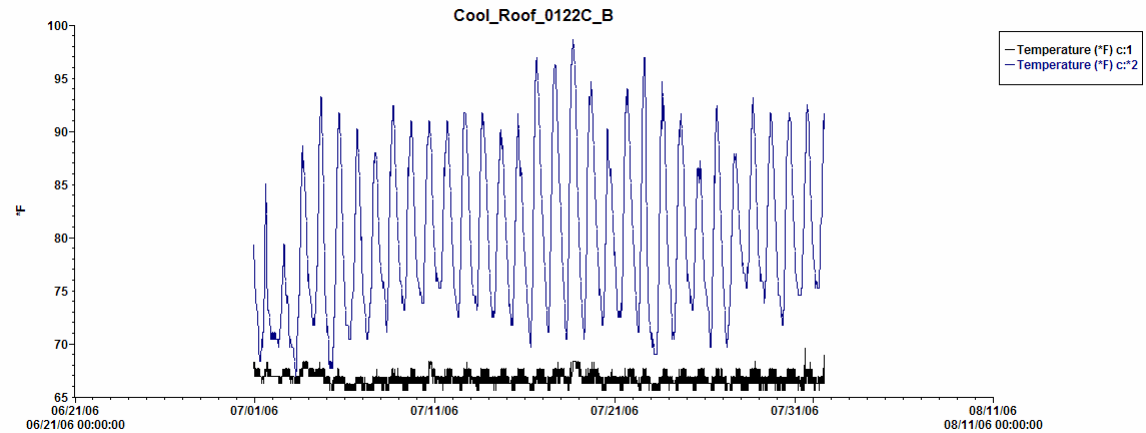
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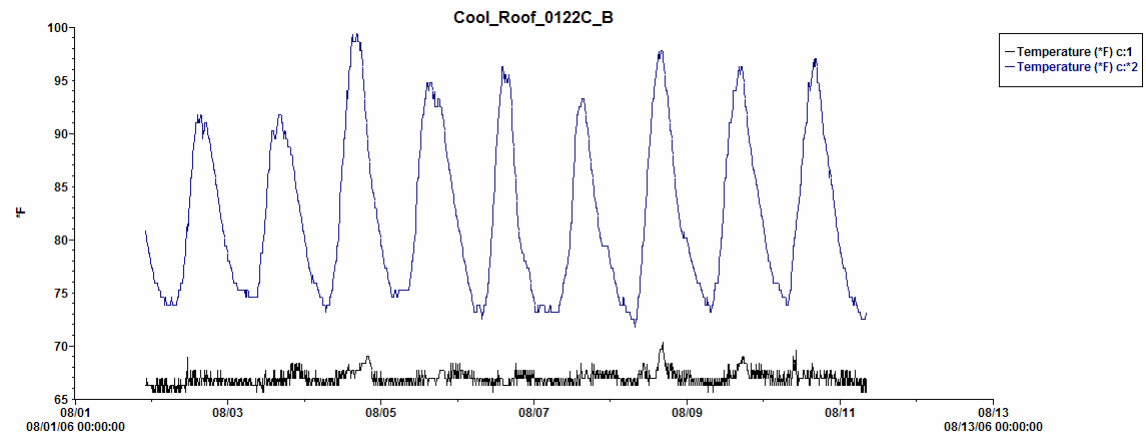
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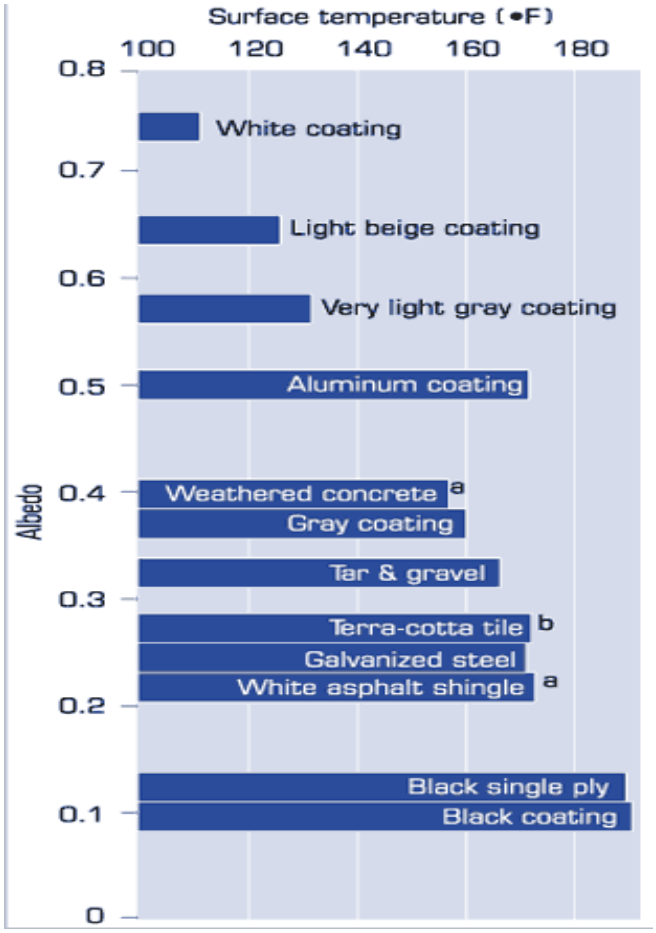
Appendix B – Literature Review

Cool Roof Technology

Background: High Albedo (read reflectance) Roofs minimize the absorption of summer heat, thereby reducing air conditioning costs. These roofs, sometimes called reflective or cool roofs, typically are white and are made of either metal, single ply membrane, or elastomeric coating (or other type of coating) over a conventional roof. Simply increasing the reflectivity of a roof surface can decrease average daily air conditioning electricity use from 13 to 16%. High Albedo roofs lower energy use by:

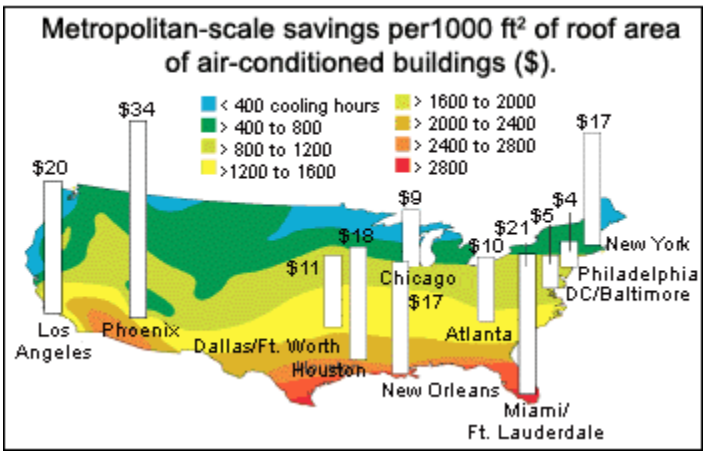
- lowering the absorption of solar energy,
- reducing surface temperatures, and
- decreasing heat transfer into a building.



Courtesy: Lawrence Berkeley National Laboratory

Notes: a. Temperatures for these materials are based on estimates rather than measurements. b. Terra-cotta tiles vary widely, depending on the mix of materials used in manufacture. Researchers at LBNL have measured cooler temperatures for other terra-cotta tile samples under comparable conditions.

As shown in the figure above, roof material albedo is crucial to roof surface temperature which translates directly into heat gain within the structure. Subsequently, mechanical equipment runtime is proportional to the sensed heat load within the space as well as thermostat set point. This being said, it is easy to relate higher roof heat transmittance to increased energy costs for facilities where cooling is the primary concern.



Courtesy: U.S. Environmental Protection Agency shown in 1993 dollars

Energy savings from high albedo roofs are climate-specific. The greatest savings will occur in buildings located in hot sunny climates. The energy savings realized are a result of reduced direct heat transfer through the roofing membrane into the building. This also takes into account any increases in heating energy. Savings estimates do not account for poor HVAC equipment performance due to higher condenser coil temperatures, nor do they account for the increased temperature of outdoor air used for ventilation. High albedo roofs tend to increase the costs for heating. However, since the cooling load dominates the heating load for most commercial buildings, the need to reduce cooling costs generally outweighs the need to reduce heating costs. [1]

1 http://www.betterbricks.com/default.aspx?pid=article&articleid=16&typeid=10&topicname=buildingenvelope&indextype=topic

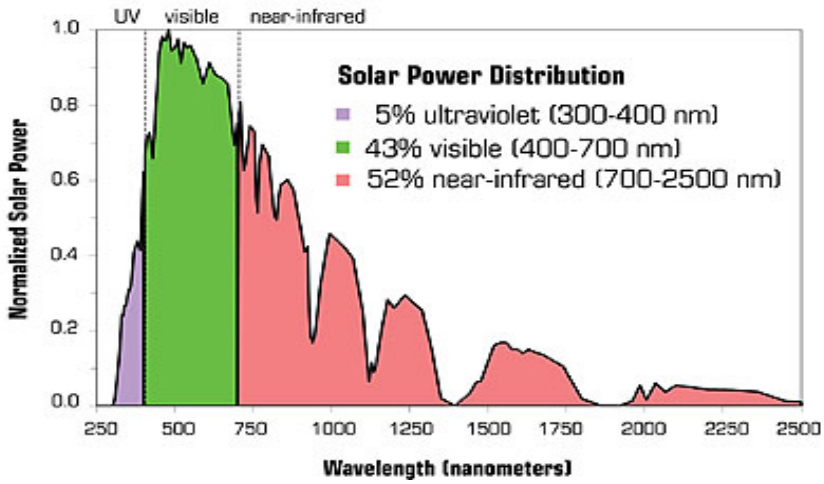


Figure courtesy of the Lawrence Berkeley National Laboratories, Berkeley, Calif.
Peak-normalized solar spectral power—more than half of all solar power arrives as invisible, "near-infrared" radiation

Most buildings are currently roofed with conventional materials: built-up roofing systems, asphalt shingles, concrete or metal seam systems. While the reflectivity of these systems is between 5 and 25 percent, the reflectivity for high albedo roofs ranges from 50 to 80 percent. Many conventional roofing materials require more maintenance and repair, since UV rays from the sun break down roofs. In addition, conventional roofing materials expand and contract daily as they go through extreme temperature changes. High Albedo roofs typically undergo less thermal fatigue. In the best applications, cool roofs have no incremental cost, delivering nearly instant payback. However, in the wrong buildings, cool roofs may actually have negative implications. The key is to know when a cool roof makes sense. Cool roofs are most effective when one or more of the following conditions exist:

- The building has high air-conditioning use, and the cooling season dominates energy considerations.
- There is little or no existing insulation. Note that an energy-efficient building should have both a cool roof and adequate insulation. When installing a cool roof or constructing a new building, you should consult local building codes and your contractor.
- The climate is hot and sunny (at least in the summer).
- New construction is planned or the existing building is scheduled for reroofing or roof maintenance.

Industry Insights: Typical cool roof technology has been centered on white or light colored material. In fact, many manufacturers of commercial roofing are now realizing the benefit of advertising their product as energy saving as well and durable and easily maintained. Many manufacturers are also seeking Energy Star certification as an added selling point for their products. These products range from elastomeric coating, to single ply membranes, to complete polymer roofing systems.

Additional Benefit:
http://www.betterbricks.com/default.aspx?pid=article&articleid=16&typeid=10&topicname=buildingenvelope&indextype=topic

Microteja®

Microteja® is a heat-dissipating coating designed to dramatically reduce the temperature of surfaces exposed to solar energy. It combats thermal shock by reducing roof heat gain through very high reflectance and emissivity plus a unique evaporative cooling process. Microteja® does the following:

- Cools surfaces by reflecting 88% to 92% of the solar energy acting on a coated surface,
- Patent pending technology extracts water from the air. As the sun rises and heats the roof, the trapped water is evaporated and the roof is cooled. Microteja® is the only product on the markets with this additional cooling feature.
- Powerful triple-cooling technology (Reflectivity, Emissivity and Hygroscopy) dramatically reduces roof heat-gain.
- Prevents constant water leakage and protects your whole roof structure by blocking thermal shock.
- Prevents the constant erosion of roof surfaces by blocking UV-energy.

Available Products

One of the original desires of the literature review was to present a list of cool roof coating products and make a comparison. However, even a quick cursory search reveals a plethora of products and suppliers; many of which are local service contractors. Thus, we have, in the interest of time and space and fact that the products are continually changing and evolving, decided not to include such a list here.

However, the EPA ENERGY STAR® Roof Products Website[2] provides an excellent overview of available cool roof products (over 1400 different coatings and roofing materials of which over 440 are coating products) from 181 different manufacturers and provides the comparison of reflectance and warranty.

[2] http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products