

# COOL ROOF CASE STUDY:

Are white roofs cooler and more energy efficient than non-white roofs?



Case study and analysis performed in August - September 2009 by:



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## Introduction: A Tale of Two Roofs

After 18 years of extreme desert heat, the roof of the [Nationwide® Scottsdale Insurance Company](#) headquarters building in Scottsdale, Arizona began the natural deterioration process. The maintenance staff had been chasing leaks for nearly five years when they hired [Alan Stevens Associates, Inc.](#) to solve the problem and bring their roof system into the 21<sup>st</sup> century.

The original roof system was a [ballasted EPDM](#) over 4" of R-20 roof insulation on a concrete roof deck, and blanketed by 2" of river rock. Compared to the modern heat resistant roofing systems used in Arizona today, this was fast becoming a major liability in regards to structural integrity, maintenance costs and energy consumption.

The new roof system installed by [Starkweather Roofing](#) in December 2008 consisted of 3" of R-19 ISO board insulation with a tight-set roofing adhesive glued to the concrete roof deck, and a self-adhesive Polyglass Eastoflex SAV base sheet and PolyKool cap sheet over the top. This roof system is capable of withstanding Arizona's infamous extreme temperatures and rapid temperature changes of the summer monsoon season.

The [PolyKool](#) sheet is white with a reflective surface (solar reflectance index value of 84) that not only meets all current and proposed energy performance standards, but also withstands constant foot traffic, ponding water and residual chemicals from the building's cooling towers.

For more information on this massive project, please [read the article](#) written about it in the July/August 2009 edition of Western Roofing Magazine.

Nationwide® Building: Before



Nationwide® Building: After





## Are White Roofs Cooler and More Energy Efficient than Non-White Roofs?

At the request of the [Arizona Cool Roof Council](#) in July 2009, [Starkweather Roofing](#) set out to determine if white roofs are indeed cooler and more energy efficient than non-white roofs. The Nationwide® Scottsdale Insurance Company roof was a perfect choice for this in-depth study.

On the morning of August 6<sup>th</sup> 2009, [Chris Walker](#) and [Sherm Robison](#) of [Starkweather Roofing](#) installed [HOBO data loggers](#) from [Onset Computer Corporation](#) directly on the roof surfaces and in the low-traffic, non-air conditioned stairwells of both the Nationwide® Scottsdale Insurance Company building and a building next door in the same corporate plaza (which still has the original ballasted EPDM roof system in place): It was a perfect “before and after” condition, being that the results would be based on identical weather conditions as opposed to data from one year to the next on the same building, where many different variables could negatively affect the results.

The temperature sensors on the roof surfaces were secured under the exact materials used in each of the current roof systems, as to not allow for the direct sunlight to impact the readings and to give an accurate surface temperature on each building. The temperature sensors placed in the non-air conditioned stairwells were secured three feet from the roof hatch and directly to the concrete roof deck to measure the energy efficiency of the roof systems (in other words, they measured how much heat was being transferred through the concrete deck into the inside of the building).



The sensors measured both the roof surface and stairwell temperatures on both buildings every hour, 24 hours per day from August 6<sup>th</sup> to September 4<sup>th</sup>. [Official temperature data for Scottsdale](#) over the same time period and at the same time intervals was obtained as well. During the data collection period Scottsdale had primarily hot sunny days, with a few monsoon storms sprinkled in which allowed for near perfect test conditions.

We say the conditions of this study were near perfect for multiple reasons. First, we had virtually identical buildings that are side-by-side. Second, one building had the old roof system and the other had the new – we could do a before-and-after analysis at the same time and under the same conditions. Finally, a concrete deck is not typical in Arizona (plywood decks are much more common). If the data proved any significant increase in energy efficiency in a building of this construction, we would know for sure that even greater results would be gained in a building of typical Arizona roof construction.

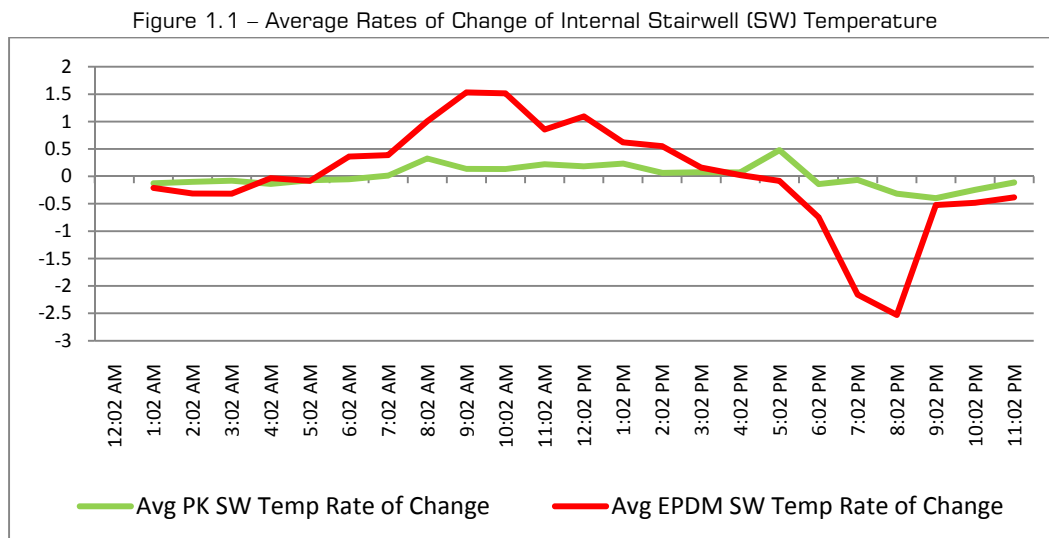
## Our Analysis and Conclusions

### Conclusion #1: White Roofs Reduce Thermal Shock

The first thing that caught our attention was the significant reduction of thermal shock, which is a direct result of the more consistent roof surface and internal building temperatures of the PolyKool roof.

[Thermal shock](#) was minimized by slowing down the rate of temperature change (both up and down) on the roof surface, which in turn nearly eliminated the rate of temperature change inside the building. The only other way to minimize thermal shock is to use materials with much greater strength, increased [thermal conductivity](#) and reduced [coefficient of thermal expansion](#) – but that approach is more expensive and doesn't guarantee as favorable of results.

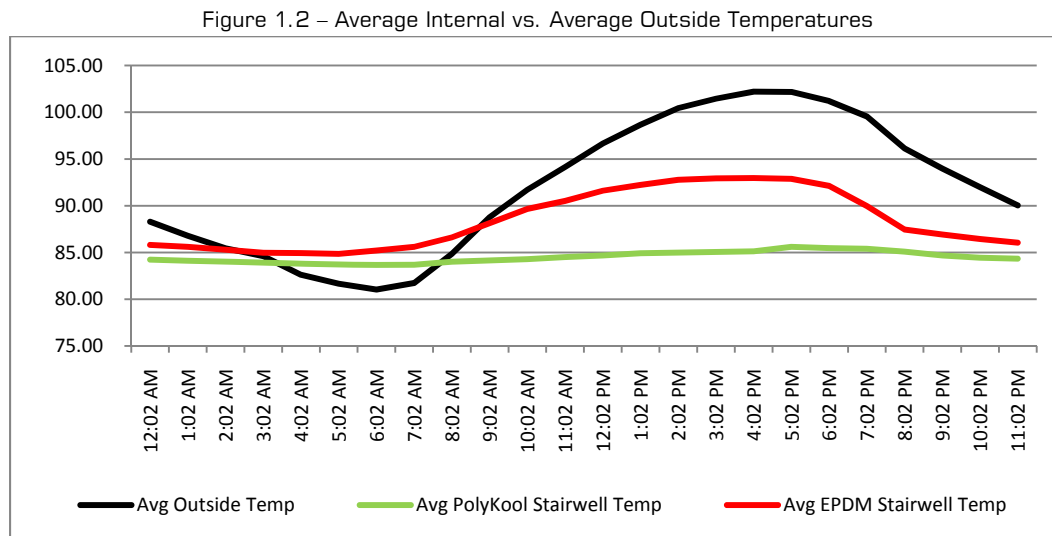
The rate of change in temperature inside the EPDM building was expected – it heats up fast, and cools down even faster. But even more surprising was just how regulated the temperature inside the PolyKool building is. The variation in temperature in the EPDM stairwell is 3.75 times that of the PolyKool stairwell. In fact, there is so little temperature variation in the PolyKool stairwell now that we are led to assume that internal thermal shock may be eliminated completely, and that maintaining a constant internal temperature is much easier as well:



Notice that between 10:00pm and 6:00am the buildings are very similar in temperature internally, but the EPDM building is always hotter than the PolyKool building. At 8:00am the EPDM building begins to heat up dramatically while the PolyKool building remains virtually unchanged. Later, between 5:00pm and 8:00pm, the EPDM building cools down even faster than it heats up – and again the PolyKool building keeps a constant internal temperature.

*continued on the next page...*

Figure 1.2 demonstrates how the internal temperatures change as a result of the temperature outside. Notice how the PolyKool building stays virtually the same all day while the EPDM building fluctuates rapidly. There is only an average range of 1.94 degrees in internal temperature from the hottest to the coolest part of the day inside the PolyKool building. Conversely, the EPDM building typically has a 7.67 degree range of internal temperature in a 24 hour period. On a building as large as these two, nearly 8 degrees means a lot in terms of the additional energy required to maintain a consistent temperature for the building's tenants.



## Conclusion #2: White Roofs Increase Energy Efficiency

Over the course of a typical hot August day in Scottsdale Arizona, a white roof is 4.62% cooler (more energy efficient) than a non-white roof. During the hottest point in the day inside the building (5:00pm), a white roof is 8.49% cooler (more energy efficient) than a non-white roof. During the maximum internal temperature increase hours of 7:00am – 5:00pm, a white roof is 6.97% cooler (more energy efficient) than a non-white roof.

Based on this data, we would suspect that the August kilowatt consumption of the building with the PolyKool roof should have reduced by approximately 7.00% or more from the previous year (when it had a ballasted EPDM roof), assuming all other items remaining equal.

In August 2008, Nationwide® Scottsdale Insurance Company headquarters building in Scottsdale, Arizona consumed 719,000 kilowatts of electricity. According to maintenance supervisor [Chris Peterson](#), all other items remained virtually unchanged from 2008, and that the installation of the PolyKool roof system was the only substantial difference in 2009. In August 2009, the kilowatt consumption was 663,000 – a 7.79% decrease (or \$5,450) in electricity required to cool the building (much more energy efficient).

Again, this is on a building with a concrete roof deck. Also note that the [PolyKool](#) cap sheet only has a solar reflective index (SRI) value of 84. If the building had a plywood roof deck (which is much more typical in Arizona) and if the SRI value of the materials used were higher (100 is typical of most high-quality roof coatings), the energy savings would be even greater. [Starkweather Roofing](#) has begun performing similar analysis using buildings with plywood roof decks as well as higher SRI value roof coatings to compare the results.

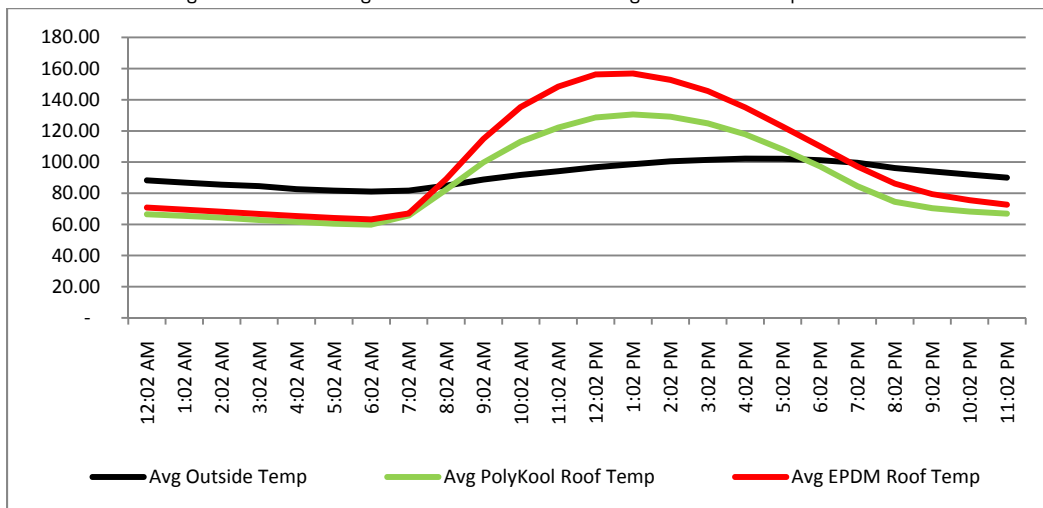
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### Conclusion #3: White Roofs Reduce Roof Surface Temperatures

The PolyKool roof is on average 12 degrees (13.57%) cooler than the EPDM roof. But that includes overnight when there is no direct sunlight.

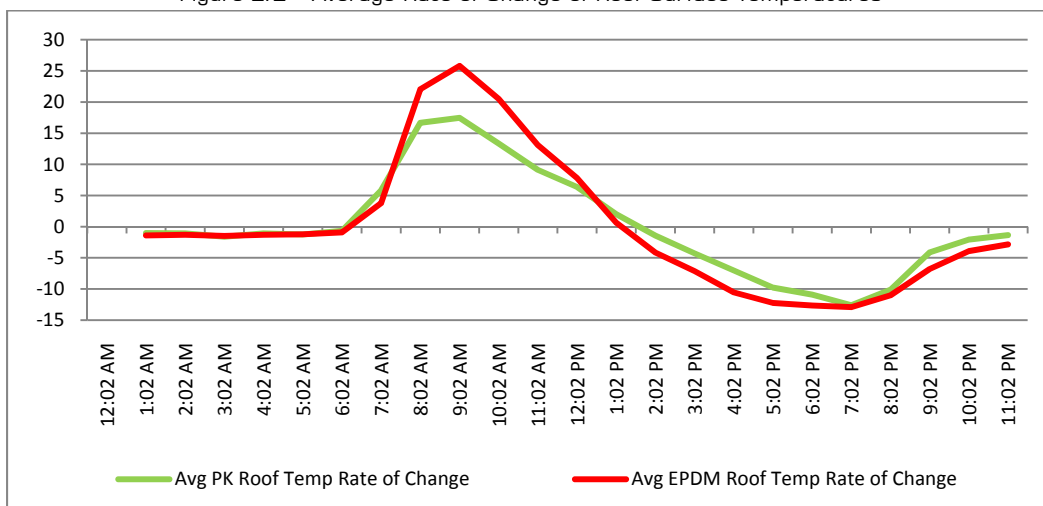
Figure 2.1 shows that 12:00pm is the largest difference in roof surface temperature over the course of our study, when the average outside temperature was 96.66°F. The EPDM roof was on average 156.28°F at that time, but the PolyKool roof was only 128.59°F. That's a difference of 27.69 degrees (the EPDM roof is 26.69% hotter). Between 9:00am and 5:00pm (the maximum sunlight hours), there is an average 22.40 degree (18.55%) difference in roof surface temperature - quite significant to the long-term survival of rooftop equipment (as well as the building's facilities workers).

Figure 2.1 – Average Roof Surface vs. Average Outside Temperatures



As demonstrated in Figure 2.2 below, the rate of roof surface temperature increase between 6:00am and 8:00am were similar on both buildings, but the EPDM roof kept getting hotter while the PolyKool building started to level off. Also, the PolyKool building cooled off more gradually than the EPDM building, which heats up really fast and becomes extremely hot, and then cools down at a faster rate (although it never gets cooler than the PolyKool roof). It isn't until 7:00pm when they come back to the same rate of temperature change. This is another indication of reduction in thermal shock with the PolyKool roof.

Figure 2.2 – Average Rate of Change of Roof Surface Temperatures



## Independent Analysis of the Data

To ensure our assessment of the two roof systems was correct, we sent the raw data to an unbiased third party who has the qualifications to properly evaluate the information.

[Richard J. Bird](#), professor of statistics at [DeVry University](#) in Phoenix, Arizona concluded the following about the data:

*"When analyzing the PolyKool and EPDM Roof temperature data, the z-test score was calculated to be -7.17. The z-critical score was calculated to be -2.33. The z-test score is much less than the z-critical score. Therefore, there is sufficient data to reject the null hypothesis and, instead, support the alternate hypothesis (the claim). It is statistically valid to claim that the PolyKool Roof temperatures are lower than the EPDM Roof temperatures. In addition the "z-test: Two samples for means" test using the Excel Analysis Toolpak calculates a  $3.74 \times 10^{-13}$  probability (essentially zero) that the temperatures are the same. The PolyKool Roof and EPDM Roof temperatures are statistically and significantly different. "*

*"When analyzing the PolyKool and EPDM Stairwell temperature data, the z-test score was calculated to be -29.5. The z-critical score was calculated to be -2.33. The z-test score is significantly less than the z-critical score. Therefore, there is sufficient data to reject the null hypothesis and, instead, support the alternate hypothesis (the claim). It is statistically valid to claim that the PolyKool Stairwell temperatures are significantly lower than the EPDM Stairwell temperatures. In addition the "z-test: Two samples for means" test using the Excel Analysis Toolpak calculates an essentially zero probability that the temperatures are the same. The PolyKool Stairwell and EPDM Stairwell temperatures are statistically and significantly different. "*

To view professor Bird's detailed analysis of the two roofs and the raw data from our study, please [click here](#).

According to Chris Peterson, Lead Facilities Technician for the Nationwide Scottsdale Insurance Company building:

*"The new roof installed on our property has given us peace of mind. The Polyglass roof does not leak and is easy to clean and keep free of debris. We used to try to clean up the old roof, but the rock ballast made this task next to impossible. The surface is so much cooler now that you can place your hand on it mid-day without discomfort. Sunglasses are now mandatory for any maintenance work, as the reflectivity is like sunshine on snow. "*

*"Our utility bill shows a consistent monthly drop in kilowatt-hour use since the roof project completion. A conservative estimate of power drop is around 50,000 Kwh a month mid-summer. The building A/C demand has dropped tremendously. The cooling tower load has decreased so much that rarely do I have all four towers online. With the old roof, we used all four towers from June to October to satisfy the building demand. "*

**Questions about this study?** Please contact [Chris Walker](#) of [Starkweather Roofing, Inc.](#)



## About Starkweather Roofing, Inc.

[Starkweather Roofing, Inc.](#) (SRI) is an independently owned and operated full-service Arizona residential and commercial roofing company with over 25 years experience. We are a licensed and bonded corporation that has grown significantly since our inception by managing and installing the right roof system for the right building. We service Arizona statewide, and are licensed in New Mexico as well.

The roofing systems we install include built-up and modified bitumen systems (both hot and cold applied); single-ply roof membranes, E.P.D.M, T.P.O and PVC, shingles, tile, foam and architectural metal roofs. We use a variety of coatings and have exemplary roof maintenance and roof cleaning programs.

SRI is a certified applicator for many roofing systems manufacturers, such as [Johns Manville](#), [Firestone](#), [Duro-Last](#), [Tremco](#), [KM Coatings](#), [Republic Powdered Metals](#), [Polyglass](#), [Eagle Solar](#), and more. For a complete list of our residential and commercial roofing services, please visit our website and click on [Our Services](#).

SRI received a Top 10 ranking in [Arizona Business Magazine](#) in 1999, 2000, 2008, and 2009, and in the [Phoenix Business Journal](#) in 2008 and 2009. We were awarded [SCF Arizona](#)'s "Best of the Best" award for workplace safety in 2006, 2007 and 2008, and were named the [Arizona Roofing Contractors Association \(ARCA\)](#) "Roofing Contractor of the Year" in 2008.

Owner [Jeff Starkweather](#) is a Board Member of the [Arizona Roofing Contractors Association](#) and of the [Arizona Cool Roof Council](#), and is Chair of the [ARCA Safety Committee](#).

SRI is a Member of the [National Roofing Contractors Association](#) and the [Western States Roofing Contractors Association](#), is an Industry Partner and Sponsor of the [Institute of Real Estate Managers \(IREM\)](#) and an Associate Member of the [Arizona Multi-housing Association \(AMA\)](#).