Photo 1
Biological growth has impeded full drainage. Reflectivity typically suffers in these areas

Photo 2
Biological growth (mildew) on the surface of Single-ply membranes in hot humid southern climates, markedly decreases solar reflectivity.

T&R UPDATE

THE REAL DIRT ON REFLECTIVE ROOFS

Single-Ply Membranes and Reflectivity Reality

by Mathew Dupuis, PhD, PE

In increasing regularity, roofing contractors are finding their projects subject to the solar reflectance requirements. These requirements are provided in model building codes. In addition, local codes and ordinances have been adopted or enacted in a number of jurisdictions.

The codified requirements reference solar reflectance ratings provided by the ENERGY STAR® Roof Products Program and the Cool Roof Rating Council's Products Rating Program. When these solar reflectivity requirements first appeared, solar reflectivity compliance could be substantiated on the basis of reflectivity measurements for new materials (initial values) or for materials exposed to three years of weathering (three-year-aged values). The three-year-aged values developed in accordance with the CRRC-S100 standard have come to represent a proxy for in-service performance. However, most in the roofing industry recognizes roof membranes can get very dirty in-service, and have questioned how accurate a predictor the three-year-aged values for reflectivity are.

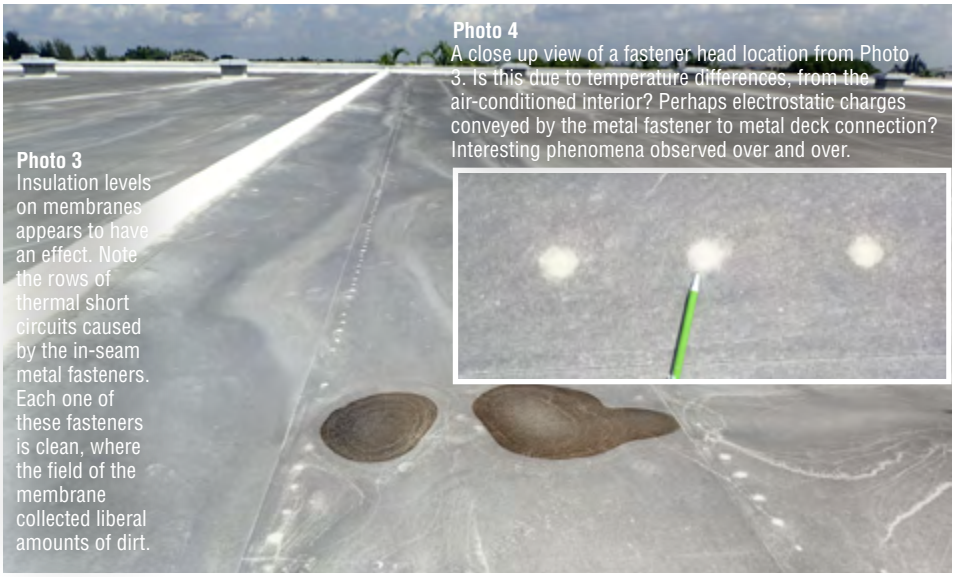

Photo 3
Insulation levels on membranes appears to have an effect. Note the rows of thermal short circuits caused by the in-seam metal fasteners. Each one of these fasteners is clean, where the field of the membrane collected liberal amounts of dirt.

Photo 4
A close up view of a fastener head location from Photo 3. Is this due to temperature differences, from the air-conditioned interior? Perhaps electrostatic charges conveyed by the metal fastener to metal deck connection? Interesting phenomena observed over and over.

Previous studies on the subject of in-service reflectivity have produced interesting results. The MRCA undertook a study of in-service reflective polymer-modified bitumen roofs in Texas during the summer of 2013 and the NRCA conducted a 5-year study of numerous roofs in the Chicago area, ending in 2015. However, these studies were geographically limited; looking only at roofs in a single geographic area. To better explore this fundamental issue of in-service long-term solar reflectance, the MRCA undertook a field study solar reflectivity for single ply roof membranes in 2015.

The Cool Roof Rating Council-S100 standard is the one which roofing manufacturers almost universally use and report as their initial solar reflectivity value and three-year-aged solar reflectivity value. In this standard, manufacturer submitted specimens are prepared and mounted outdoors on sloped racks. These racks are positioned in three climates around the United States. These climates, per the CRRC-S100 standard, include Hot/Humid climate, Cold/Temperate climate and a Hot/Dry climate. Once the samples have been exposed for three years they are measured for their solar reflectance.

Given the prescribed aging locations in the CRRC standard, it was obvious that this current study should utilize these same climates. The CRRC standard gives examples of cities that meet the prescribed climates. This study utilized examples cited in this standard; for a Hot/Humid climate, Miami, Florida, for a Cold/Dry climate, Chicago, Illinois and a Hot/Dry climate, Phoenix, AZ was used.

Incorporated by reference into the CRRC-S100 standard is ASTM C1549 - 09(2014) Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer. The portable solar reflectometer that is described in the ASTM C1549 standard is the Solar Spectrum Reflectometer (SSR) from Devices and Services Company, Dallas, TX. This reflectometer has been in use for decades and is the basis for almost all published data on roof membrane solar reflectivity. The NRCA provided the MRCA with their SSR and an operator, for this study. Immediately prior to the testing program the SSR unit had been returned from the manufacturer for calibration and updates.

Single-Ply roof membranes currently dominate the United States low slope roofing market. The three membranes that are the current predominate choices are TPO, PVC and EPDM. This dominance in the low-slope roofing market made these single-ply membranes the obvious choice for this study.

Member roofing contractors of the CRCA, FRSA and or WSRCA provided all of the subject roofs utilized in this study. A strict distribution of roof membrane types or building occupancies were not prescribed to these contractors. These contractors were only asked to provide highly reflective single ply membranes, i.e. White TPO, White PVC and White EPDM. From this directive, these contractors merely provided a sampling of their local roof membrane population. Table 1 details the distribution of membrane types in each climate zone for this study.

Photo 5
Dust from manufacturing operations under the roof are ejected onto the roof by the vent unit. Once the air velocity drops sufficiently the dust is dropped and solar reflectivity suffers.

Inventory				
	Chicago	Miami	Phoenix	Totals
TPO	20	28	19	67
PVC	4	2	10	16
White EPDM	6	0	0	6
Other	0	0	1	1
Total	30	30	30	90

Table 1. Inventory of Single-Ply Roof Membranes Measured

It would be preferred to measure in-service roofs that exactly match the three years of exposure that is specified on product data sheets. However, this constraint is impractical when discussing the in-service population of roofs, as a whole. However, the MRCA did request a target age of three years from the participating contractors in each climate. Figure 1 is a histogram of the ages for all the measured roofs, in all climates.

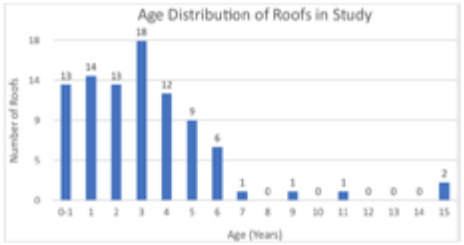

Figure 1 Histogram of all roofs measured in this study. Ages are truncated to the year.

On each of these 90 roofs, 30 random readings were taken with the SSR reflectometer. An important aspect of this research was the random nature of these readings. The majority of these randomly selected areas may fall in the field of the roof, but could also be near drains, near wall flashings, around roof top ventilators, or around any other roof top feature. In essence, no horizontal (low-slope) area of the actual roof membrane surface was considered out of bounds for random sampling. Vertical surfaces covered in roof membrane, such as parapet walls and equipment curbs, were not sampled.

For each roof, the 30 random readings were averaged to give the sample mean. In Figure 2 the sample means

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for all 90 roofs are displayed. The information in Figure 2 should generally impress, in that the current in-service inventory of roofs is returning respectable numbers. The average reflectivity of all roofs and all readings for this study was 63.6%. Consider that from the 1980's through 2010 the dominant roof membrane in the United States was black EPDM; which will return a solar reflectivity between 7-10%.

Figure 2 Plot of sample means of fractional solar reflectivity for all roof membranes in this study, against their reported age.

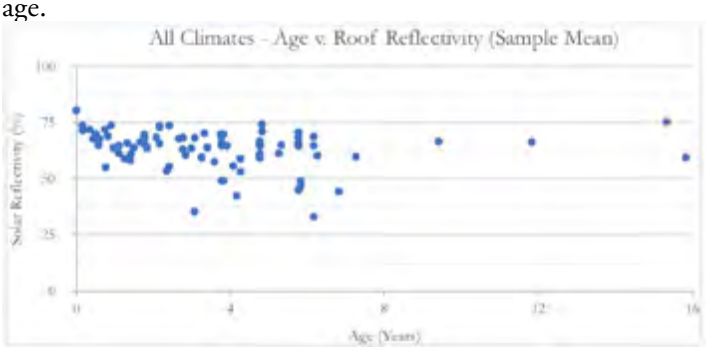


Figure 2 represents the measured sample mean reflectivity for each roof sampled. All but one membrane in this study has a CRRC three-year-aged solar reflectivity recorded in their publicly accessible database. If we take the difference between the three-year-aged value recorded in the CRRC database and the sample mean, from this study, for each of these membranes, we arrive at Figure 3.

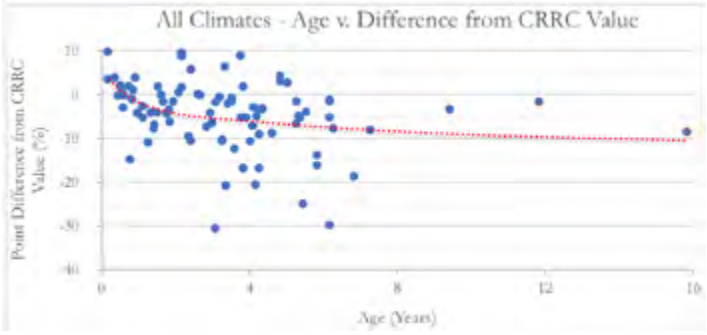


Figure 3 Plot of normalized fractional difference between roof sample mean and CRRC database reported three-year-aged value.

The pattern produced by the data in Figure 3 is enlightening. The most basic observation that should be made is that the solar reflectivity value returned by the CRRC-S100 test method appears to not to correctly predict actual in-service roof reflectivity. If it did, trend line would at least pass through "0" as a differential at three years. It does not. Statistical measures of this data confirms the visual observation of Figure 3, that the CRRC-S100 roof membrane aging methodology does not match in-service roofs.

If we break the data down further, say into membrane versus climate zone, we arrive at Table 2.

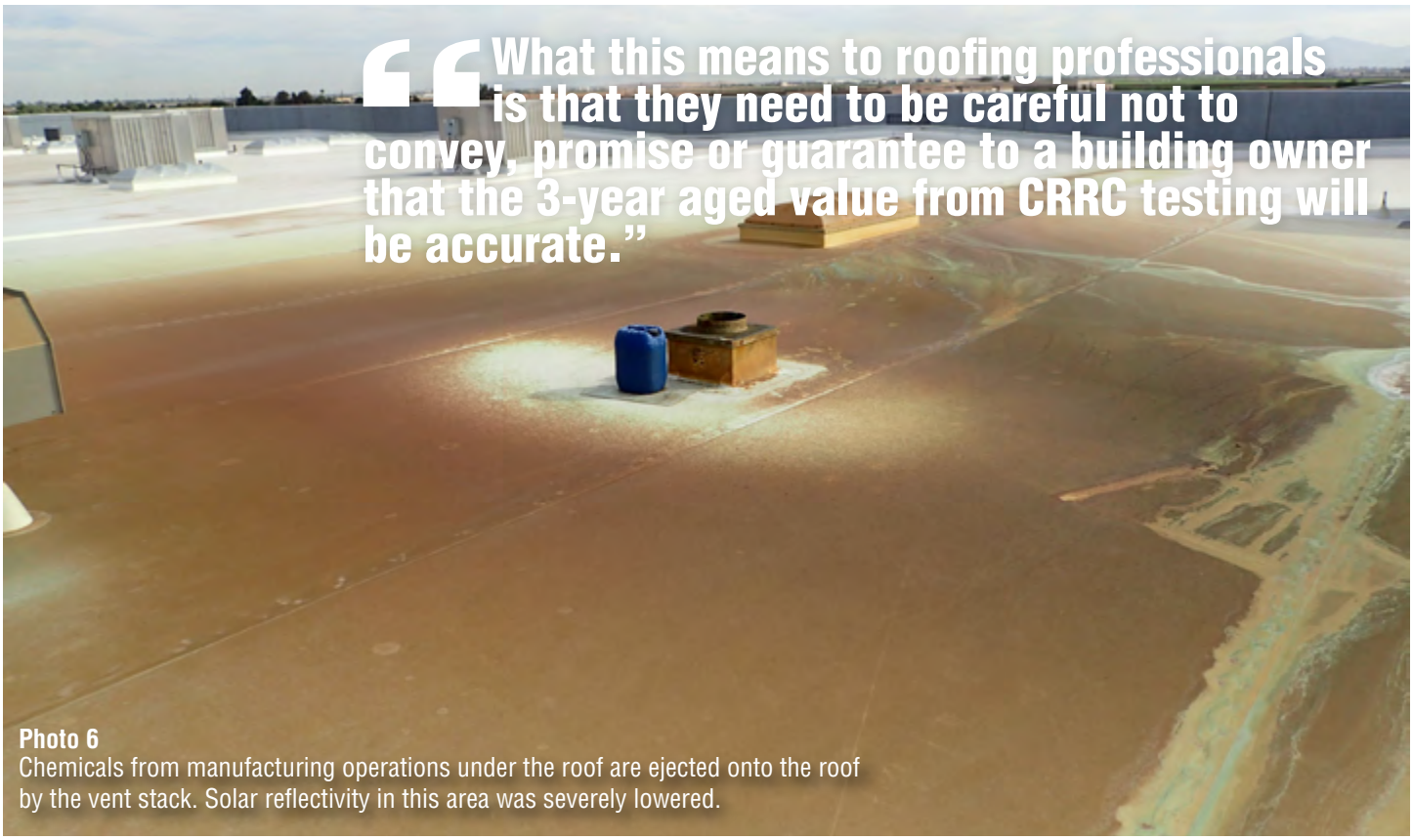
Normalized Difference from CRRC Aged (SSR)				
	Chicago	Miami	Phoenix	Totals
TPO	-6.4	-3.5	-1.3	-3.7
PVC	-9.7	-4.6	-14.4	-12.0
White EPDM	5.6	-	-	5.6
Average	-4.4	-3.6	-5.8	-4.6

Table 2. A break down of Membrane Class versus Climate Zone

The CRRC-S100 test is in the author's opinion an idealized aging test. The membrane samples are aged outdoors, but under ideal conditions. These samples are not challenged by numerous deleterious conditions found on any common in-service roof. These deleterious conditions include, but are not limited to:

1. Climate zone
2. Drainage Impediment
3. Roof Slope
4. Predominant Wind Currents
5. Aerodynamics of Building
6. Building Occupancy
7. Local Pollutants
8. Membrane Surface Condition
9. Biological Growth
10. Place of Manufacture
11. Insulation Amount
12. Air Handling Unit Exhaust
13. Overhanging Foliage
14. Dust Storms

Any or all of these conditions may be present on a roof. The effect of climate zones is apparent in Table 2. The buildup of dirt and organic matter in poorly drained roof areas, Drainage Impediment, can easily be seen from satellite imagery as easily as on the roof level. The impact of Roof Slope has been investigated by the NRCA. The Place of Manufacture was seen on several roofs in this study. In one case the same roof membrane, from the same manufacturer, but manufactured at two separate plants produced a differential of 0.04 between two adjacent membrane sheets on the same roof, installed at the same time. Of the most interesting issues was the Dust Storms that local contractors in Phoenix, AZ referred to as a "Haboob". The dust brought to the roof by the Haboob was evident on the PVC roofs and generally not present on the TPO roofs, in Phoenix.



> **“What this means to roofing professionals is that they need to be careful not to convey, promise or guarantee to a building owner that the 3-year aged value from CRRC testing will be accurate.”**

Photo 6
Chemicals from manufacturing operations under the roof are ejected onto the roof by the vent stack. Solar reflectivity in this area was severely lowered.

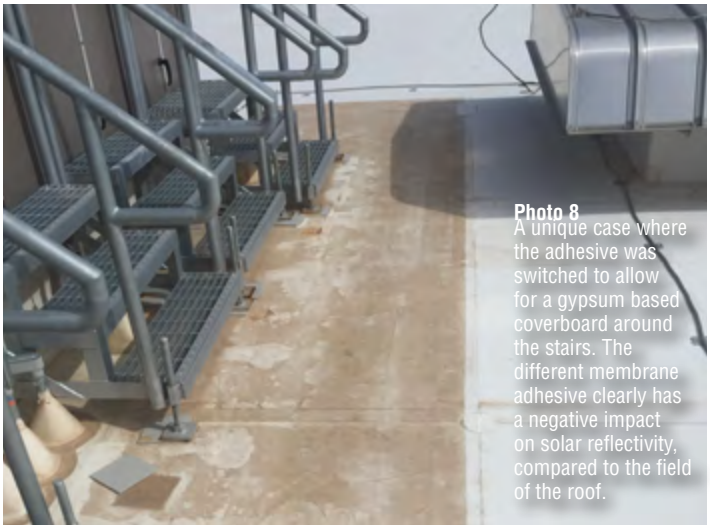


Photo 8
A unique case where the adhesive was switched to allow for a gypsum based coverboard around the stairs. The different membrane adhesive clearly has a negative impact on solar reflectivity, compared to the field of the roof.

Photos 1 – 10 show these various deleterious conditions that the author observed during this study. These same conditions roofing professionals observe every day.

Therefore, based on the observations made during this field study, the author with combined decades of experience and thousands of roofs observed believes that deleterious conditions such as these combine in almost infinite combinations on our in-service roofs. As such a prescribed aging test, does not adequately capture these effects.

What this means to roofing professionals is that they need to be careful not to convey, promise or guarantee to a building owner that the 3-year aged value from CRRC testing will be accurate. This research and others like it show that not to be the case.

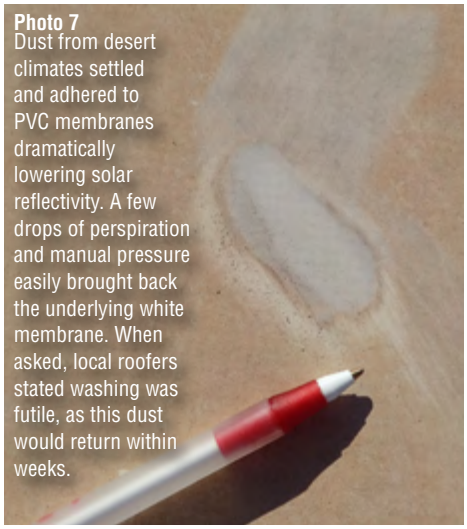


Photo 7
Dust from desert climates settled and adhered to PVC membranes dramatically lowering solar reflectivity. A few drops of perspiration and manual pressure easily brought back the underlying white membrane. When asked, local roofers stated washing was futile, as this dust would return within weeks.

The reflectivity data manufacturers provide, from the CRRC-S100 test protocol remains a good metric for roof membrane comparisons and meeting prescriptive building code requirements. More specifically it allows consumers and specifiers to make educated comparisons about the long term solar reflectivity performance between different roof membranes; as they were tested under the same conditions. Ergo, one could compare the aged reflectivity of three different single-ply sheets, perhaps of the same polymer type, perhaps not, and make educated comparisons about their aged reflectivity performance. But alas, each membrane may soil differently when it is installed and be subject to the numerous variables above.