Online Publications List

Reference Publication: Parker, D S, J E R McIlvaine, S F Barkaszi, D J Beal and M T Anello (2000). Laboratory Testing of the Reflectance Properties of Roofing Material. FSEC-CR670-00. Florida Solar Energy Center, Cocoa, FL.

Laboratory Testing of the Reflectance Properties of Roofing Materials

Revised July 2000*

D.S. Parker
J.E.R. McIlvaine
S.F. Barkaszi
D.J. Beal
M.T. Anello

Florida Solar Energy Center (FSEC)
1679 Clearlake Rd.
Cocoa, FL 32922-5703

Table of Contents

Introduction

Past simulation and test cell studies have shown potential reduction to building cooling loads from higher exterior surface solar reflectances (Givoni and Hoffman, 1968; Givoni, 1976; Chuan and Busching, 1983; Griggs and Shipp, 1988; Anderson, 1989; Akbari et al., 1990; Chandra and Moalla, 1991; Bansal et al., 1992). Furthermore, simulation analysis of macro-climatic effects have shown that light colored surfaces may reduce the magnitude of the urban heat island (Taha et al., 1988; Akbari et al, 1989; Akbari et al., 1992).

Figure 1 shows a graphic illustration of the potential influence of surface reflectance on roof solar heat gain.

The two photographs show three homes recently rebuilt in a South Florida neighborhood, taken both with a conventional and infrared camera. The roofs of the three homes are depicted in the infrared image at 4:53 PM on July 19th. The camera is looking west so that the roof sections seen are those facing east. The infrared color scale shows the surface temperatures of the captured image from 77^{o}F (dark blue) - 113^{o}F (white) in 3.6^{o}F increments. All three homes have asphalt shingle roofs; the one nearest has dark gray shingles, the middle home has white shingles and the furthest house has cobalt blue shingles. The thermograph reveals the expected behavior: the dark gray roof has a surface temperature in excess of 113^{o}F (white on IR scan) whereas the lighter colored white shingle roof is approximately 10^{o}F cooler (red). The temperature of the blue shingle roof is in between (red-magenta).

Recent monitoring experiments suggest that increasing roof solar reflectivity may significantly reduce cooling loads in occupied residential and commercial buildings (Boutwell et al., 1986; Akbari et al., 1992; Parker et al., 1993). Since roofs receive a significant concentration of incident solar radiation and are typically difficult to shade, they provide a natural focus to attempts to improve building solar reflectance.

Other studies have identified solar reflectance as a primary property responsible for surface heat gain reductions (Anderson et al., 1991, Bretz et al., 1992). Several investigations have accumulated data on the solar reflectance of roofing materials (Wechsler and Glaser, 1996; Reagan and Acklam, 1979; Taha et al., 1992). However, specific data is still sparse and Rosenfeld et al. (1992) have identified the need for additional testing of roofing system types as well as uniform standards for testing of coatings and paints. Consequently, this report adds to the body of knowledge on the measured reflectance of roofing systems. Spectral reflectance properties were measured in the laboratory on 37 samples of differing roofing materials. A total of 21 of these were performed recently; the other 16 were performed last summer. Identical test procedures were used for all samples.

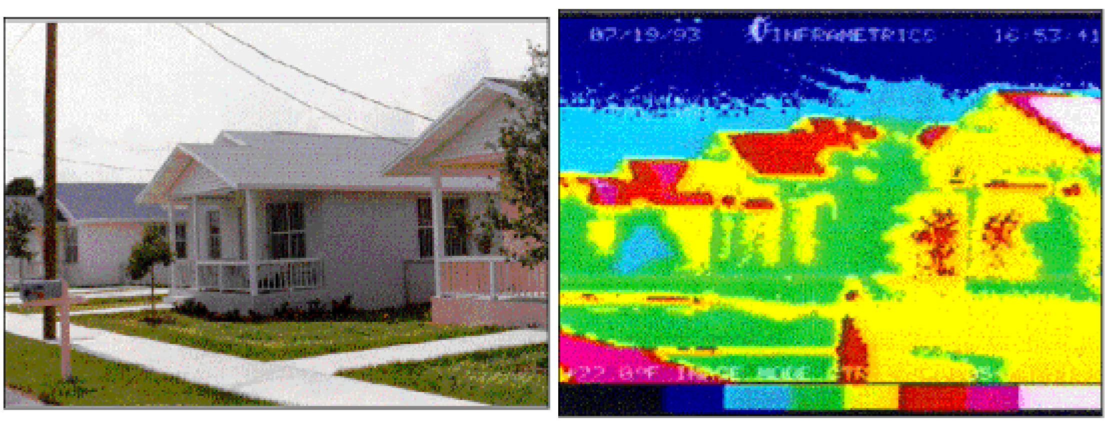

Figure 1. Comparison of asphalt shingle color influence on roof heat gain.

Description of the Tests

Testing of the roofing material samples was performed by *DSET Laboratories*. All measurements were made on the uncoated surface of the specimens. The hemispherical spectral reflectance measurements were performed according to ASTM Standard Test Method E903-88. A *Beckman 5240 Spectrophotometer* using an integrating sphere was utilized. Total reflectance measurements were obtained in the solar spectrum from 300 - 2500 nm at an incident angle of 15 degrees. The spectral data was integrated against Air Mass 1.5 global spectrum (ASTM E892-87, Table 1) to yield 109 weighted ordinates over the total spectral bandwidth.

Infrared reflectance measurements were performed according to ASTM E408-71, Method A. A *Gier Dunkle Instruments Infrared Reflectometer Model DB 100* was used for the measurements. Five measurements were made of each sample, the indicated value represents their average.

A total of 37 roof material samples were tested including eleven differing asphalt shingle swatches. The test results provide six types of data:

1) Hemispherical spectral reflectance of the samples over the solar bandwidth from 300 - 2500 nm. (ASTM Standard Test Method E903-88)
2) Integrated solar reflectance of the above from 300 - 2500 nm.
3) Integrated UV reflectance of the above from 300 - 400 nm.
4) Integrated visible reflectance of the above from 410 - 722 nm.
5) Integrated Near Infrared (NIR) reflectance of the above from 724 - 2500 nm.
6) Long-wave infrared reflectance of the samples, allowing calculation of emittance. (ASTM E-408-71)

The most pertinent properties in the thermal performance of roofing is the total solar reflectance and the infrared emittance of the samples. Ideally, a roofing system designed to reduce cooling loads would have a very high solar reflectance (rejects solar radiation) with a very high infrared emittance (readily emits any collected heat).

Test Results

Asphalt Shingles

The first ten of the products tested were commercially available asphalt shingle samples of various colors (*Owens Corning Fiberglass*). Asphalt shingles make up more than half of the residential roofing market in the southern United States (NRCA, 1993). Recent trends show that the market in the sunbelt still favors lighter pastels such as white and gray, although there is a movement to bolder colors and greater consideration of "exterior aesthetics" (RSI, 1993). Figure 2 depicts small 1 x 2" sections of several of the shingles. The test results for the shingle samples are provided in Table 1.

Table 1. Reflectance and Emittance Properties of Asphalt Shingles

Shingle Color	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
Aspen Gray	17.8	8.9	19.5	17.2	0.91
Weathered Wood	8.2	5.4	8.4	8.3	0.91
Autumn Brown	9.6	3.9	8.6	11.1	0.91
Surf Green	15.7	9.1	16.2	16.1	0.91
Beachwood Sand	20.0	7.5	20.5	20.8	0.91
Ocean Gray	11.7	7.2	12.3	11.5	0.91
Onyx Black	3.4	3.7	3.5	3.3	0.91
Desert Tan	12.0	4.3	11.3	13.5	0.91
Island Brown	8.7	4.4	7.8	10.0	0.91
Shasta White	26.1	11.5	29.6	24.2	0.91
Generic Grey	21.7	10.1	23.1	21.7	0.91
Generic White	25.3	9.9	27.0	25.2	0.91

Generic Black	5.0	4.6	5.3	4.8	0.91
ISP K-711 "White"	31.1	12.2	34.4	29.9	0.92

The solar reflectance of the shingle samples was uniformly low, varying from 3.4% (Onyx Black) to 26.1% (Shasta White). In general the white and gray specimens had the highest reflectances followed by the light brown colors. We also tested an experimental asphalt shingle product. The ISP K-711 sample was a shingle sample specifically produced by *ISP Minerals* for FSEC testing. It is intended to represent the whitest shingle which manufacturers can produce using the existing granulation process. Its reflectance was improved at 31.1%, but only slightly over conventional white shingle products.

Coating Products

We also tested a number of reflective coating products, some of which are being used in FSEC field experiments[1]. All samples were of a white color except for the *Lo-mit* material which has a metallic silver appearance.

Table 2. Reflectance and Emittance Properties of Reflective Coatings

Specimen	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
Kool Seal Elastomeric over shingle	71.4	16.7	80.0	69.1	0.91
Aged Elastomeric on plywood	72.7	17.4	78.5	73.1	0.86
Flex-tec Elastomeric on shingle	65.0	14.1	69.4	66.3	0.89
Insultec on metal swatch	77.8	18.4	79.9	82.0	0.90
Generic Coating on metal swatch	77.4	16.2	82.2	79.3	0.91
Lo-mit on shingle	54.1	50.9	53.3	55.2	0.42

We applied two coats of *Kool Seal* elastomeric coating to a gray asphalt shingle that was tested. *Kool Seal* is an elastomeric product that FSEC is using in a series of roof coating experiments this summer. The superior reflectance of such coatings, compared with conventional white asphalt shingles is evident. The measured solar reflectance as applied was 71.4%. Three other coating products were tested: *Insultec, Flex-tec* and the generic coating all of which had high solar reflectances of 65 - 77%. It should be noted, however, that the measured reflectances of *Insultec* and the generic coating were made on samples applied to 4.5" x 4.5" sections of thin flat metal; their *in situ* reflectance when applied to shingles may be no different from the *Kool Seal* or *Flex-tec* elastomeric products. This points out the need for a consistent sample surface for comparative evaluation of paints and coatings.

We also tested a weathered sample of a white elastomeric coating which had been on the cupola roof of the Passive Cooling Laboratory at FSEC for approximately five years. The sample evidenced little apparent degradation in reflectance properties compared with new product samples. Finally, we tested *Lo-mit,* a product intended for use as a radiant barrier, but also advertised for use as a reflective roof coating. We found the solar reflectance of the product to be considerably lower than that of the other tested elastomeric coatings. It also exhibited a lower far-infrared emissivity which we expect would also compromise performance.

White Metal Roofing

Two white metal roofing samples were tested. White metal roofing represents an attractive option for buildings which plan to use this roofing type; typically a white color has no cost premium relative to any other color. A low cost siliconized polyester white painted metal roof had a tested reflectance of 59%. Another metal roof sample with a premium white *Kynar* paint had a measured reflectance of 67%.

Table 3. Reflectance and Emittance Properties of White Metal Roofing

Specimen	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
MBCI Siliconized Polyester White	58.9	17.3	63.8	58.6	0.85
Atlanta Metal Products Kynar Snow White Off-White Metal (Bradco)	 66.6 55.5	 18.2 15.3	 73.2 59.8	 65.4 55.7	 0.85 0.89
McElroy 24-gauge White Metal	66.8	17.5	72.8	66.2	0.89

Various Colors of Metal Roofing

With the growing popularity of metal roofing, we tested a dozen samples representing much of the color variation for this roofing type. The samples were obtained from Clad-Tex Metals, Inc. for their 24-gauge product using Kynar finishes. The samples are show in Figure 3.

Table 4. Reflectance and Emittance Properties of Metal Roofing

Specimen	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
Bone White	66.1	18.1	74.2	63.5	0.88
Sandstone	50.1	15.4	53.3	50.7	0.88
Classic Green	11.2	6.5	8.4	14.3	0.89
Patina Green	24.3	10.5	22.7	27.4	0.88
Hartford Green	8.5	6.7	7.4	9.8	0.86
Pacific Blue	17.7	10.3	14.2	21.8	0.90
Slate Blue	19.5	12.2	20.6	19.2	0.90
Matte Black	5.6	5.6	5.2	6.1	0.90
Burgundy	12.4	5.2	8.0	17.4	0.90
Cardinal Red	36.9	4.8	22.1	54.4	0.89
Coral	34.4	9.8	29.6	41.6	0.88
Musket Gray	13.1	9.1	14.3	12.4	0.90

Concrete and Cement Roofing Tiles

Before the advent of residential air conditioning, white concrete barrel tile roofs were very common in South Florida. The reflectance data indicates that this choice has excellent thermal properties. A white concrete tile sample had a reflectance of 73% whereas a red tile had a reflectance of only 18%. A white cement shingle (*Supradur*) also exhibited high reflectance (77%).

Table 5. Reflectance and Emittance Properties of Concrete and Cement Roofing Tiles

Specimen	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
Red concrete tile	17.6	7.0	13.1	23.1	0.91

Unpainted cement tile	24.8	9.7	18.1	32.8	0.90
White concrete tile	72.8	22.0	77.7	73.4	0.90
White cement shingle	76.6	18.1	85.9	74.0	0.88

Red concrete tiles are currently very popular in Florida, due to their pleasant aesthetic appearance. Unfortunately, the data shows their overall solar reflectance to be fairly low although the reflectance values in the near infrared range are somewhat better. Although not tested in our study, Reagan and Acklam (1979) have measured the solar reflectivity of red clay mission tiles at approximately 26%.

Various Colors of Cement Roofing Tiles

To determine the variation of solar reflectance from differing colors of concrete roofing tiles, we had nine representative roofing tile sections tested. All were standard colors available from *Monier Lifetile*. A number of the tiles were mottled in color and required two reflectance tests to establish overall reflectance. Each sample is coded according to the manufacturer designation and is shown in Figure 4.

Table 6. Reflectance and Emittance Properties of Colors of Tile Roofing

Specimen	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
300 - Colonial Slate White	72.8	27.1	76.5	74.2	0.93
302A - Colonial White Gray	33.6	13.1	34.4	35.0	0.93
302B - Colonial White Gray	67.3	23.3	70.0	69.3	0.93
303A - Colonial Amber Sand	56.3	21.2	48.9	67.0	0.94
303B - Colonial Amber Sand	61.9	40.6	59.9	66.2	0.93
308A - Colonial Mission Sunset	38.6	10.8	32.2	47.7	0.93
308B - Colonial Mission Sunset	23.4	6.2	18.3	30.1	0.94
330A - Buffy Flash	43.1	19.2	39.1	49.3	0.94
330B - Buffy Flash	28.1	11.7	23.3	34.3	0.93
348A - Tequila Sunset	34.0	8.9	27.0	43.4	0.94
348B - Tequila Sunset	21.7	7.7	17.5	27.3	0.94
MRD - Medium Red	24.0	5.8	14.8	34.7	0.94
MRW - Medium Dark Red	23.0	6.0	14.3	33.1	0.93
TAU - Taupe	18.9	11.2	18.1	20.5	0.95
Flat White Tile	77.3	33.5	80.6	78.7	0.94

Painted Wood Shingles

Two wood shingle samples were supplied by Lawrence Berkeley Laboratories (LBL). LBL is interested in developing information on paints and coatings which have absorptive properties in the visible range, but are reflective in the near infrared region (NIR). The U.S. Navy has already performed work demonstrating the possibility to tailor formulated coatings that are selectively reflective in the NIR region (Brady and Wake, 1992). Light gray colors have been developed with NIR reflectances in excess of 75%. Both wood shingles were coated with a light brown paint (#32015). However, the second specimen had a white undercoat with a thin 1.6 mil thickness brown tint applied over it in hopes of obtaining improved spectral reflectance in the NIR region.

Table 7. Reflectance and Emittance Properties of Painted Wood Shingles

Shingle Color	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
Wood shingle - 30215 Brown	21.9	6.5	17.6	27.6	0.90
Wood shingle - #6 tinted 1.6 mils	22.1	5.2	18.2	27.5	0.91

The brown painted wood shingle had a solar reflectance of approximately 22%[(2)]. The other sample with a tint, supposedly reflective in the NIR region did not show appreciably different characteristics. However, both samples possessed NIR reflectances considerably greater than those in the visible range.

Roofing Membranes

Single ply roofing membranes are becoming very common in the commercial roofing industry. We tested samples of white and black EPDM products to determine the relative advantage of the more reflective products since they represent a common low-cost option for many new commercial buildings.

Table 8. Reflectance and Emittance Properties of Single Ply Roofing Membrane

Shingle Color	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
Black EPDM	6.2	6.7	6.4	6.0	0.86
Grey EPDM	23.1	13.5	27.2	20.2	0.87
White EPDM	68.7	16.7	68.3	75.0	0.87
White T-EPDM	80.6	16.7	88.7	79.8	0.92
Hypalon	75.5	17.3	81.2	76.4	0.91

As expected, the results showed that white EPDM and *Hypalon* products possessed the highest solar reflectances (69 - 81%).

Other Roofing Systems

We also tested several other roofing types. This included unpainted aluminum roofing, as well as unpainted galvanized "tin" roofing. We also examined bitumen roofing materials since they are very commonly used for commercial buildings.

Table 9. Reflectance and Emittance Properties of Other Roofing Materials

Specimen	Reflectances %				Far Infrared Emittance
	Solar	UV	VIS	NIR	
Unpainted aluminum	71.3	75.0	74.0	68.7	0.04
Unpainted galvanized	60.9	29.3	49.4	73.5	0.25
Smooth bitumen	5.8	4.2	5.2	6.6	0.86
Granular surface bitumen	25.8	9.3	28.4	25.0	0.92

Although the unpainted aluminum and galvanized surfaces showed good reflectance properties, both materials had relatively low emissivities that would compromise their performance in application. Also, both samples were new and can be expected to lose both their reflective as well as low emissive properties as they tarnish over time.

Spectral Characteristics of Reflective Roofing Systems

Although total solar reflectance is the most important property to a reflective roof system, another desirable aesthetic characteristic of heat rejecting roofs might be termed the visible to heat reflectance ratio:

$$VHR = VIS_r / NIR_r$$

Where:

VHR = Visible to Heat (NIR) reflectance index (dimensionless)
VIS_r = roofing surface reflectance in the visible spectral region (410 - 722 nm)
NIR_r = roofing surface reflectance in the near infrared region (724 - 2500 nm)

The lower the value of the index, the better the ratio of near infrared heat rejection to reflected visible light. Lower values indicate a spectrally selective characteristic for reflective roof systems. The primary advantage is that of a better level of thermal performance for a given level of glare from the roofing system. Ideally a building would have a lower visible reflectance than that in the near infrared (NIR) region. This would reduce potential glare problems from reflective roofing systems. Conversely, we find that most of the tested options had a higher visible reflectance than in the near IR region. In examining the ratio of visible reflectance to that in the near IR region, we found that the tested brown paints from LBL, and the unpainted cement and red tile sample had ratios less than one.

It should be noted, however, that physical circumstances work against the theoretical potential of such a concept. The energy intensity of the solar spectrum (W/m^2 nm) is highest in the visible range and some 60% of overall solar energy content is contained in this region. The spectral distribution of solar radiation both for an air mass of one is shown in Figure 5 (Thekaekara, 1974). The implication is that a "spectrally selective" roof system which is primarily reflective in the NIR and/or UV portions of the spectrum will automatically compromise performance relative to a high uniform reflectance.

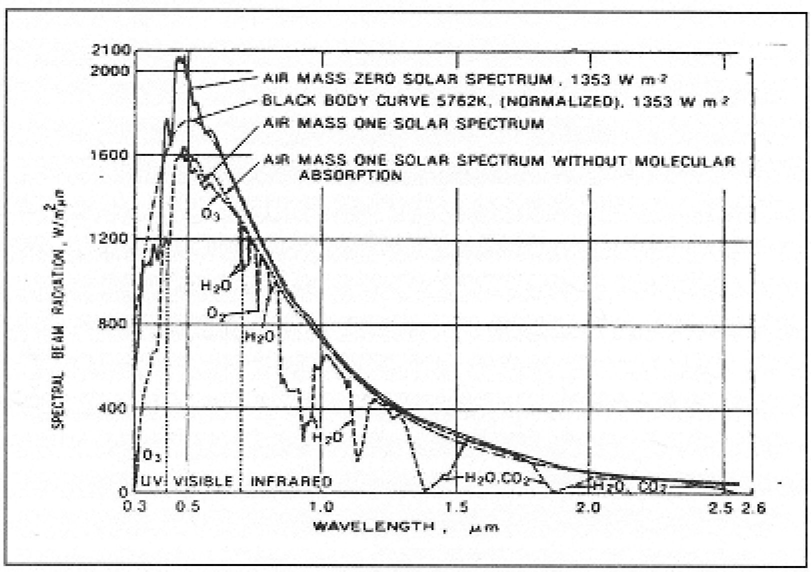

Figure 5. Spectral distribution of solar radiation.

In one sense, white building products are already spectrally selective, in that they reflect solar radiation in the 400 - 2500 nm region, while being very emissive in the far-infrared zone from 4,000 to 18,000 nm. Figure 6 shows the solar reflectance and far-infrared emittance of selected building materials (Fairey, 1986). Materials with the greatest potential for heat rejection appear in the upper left hand corner of the figure where the properties of high solar reflectance and far-infrared emissivity dominate. The desirable characteristic of high long-wave emittance was met by most of the tested samples. Those with low emissivities were the unpainted aluminum, galvanized and *Low-mit* samples. As pointed out by Rosenfeld (1992), low-emissivity products can be expected to have a poorer thermal performance (higher surface temperature when exposed to sunlight) relative to a comparable material with a high far infrared emissivity and a similar solar reflectance.

Conclusions

FSEC has sponsored testing on over 60 samples of common roofing materials. The testing provided data on the spectral reflectance characteristics of the samples. Data was also provided on the reflectance properties as integrated over the ultraviolet (UV), visible (VIS) and near infrared (NIR) portions of the solar spectrum. Tests were also performed on the far-infrared reflectance of the samples allowing calculation of their emittance. The results suggest the following conclusions:

- All colors of asphalt shingles evidence poor solar reflectance (3 - 26%)
- An improved white asphalt shingle using the conventional process showed only modest improvement (31% reflectance)
- White elastomeric coatings showed high solar reflectance (65-78%)
- Other white roofing systems showed high solar reflectance:
  - White concrete tile: 73%
  - White metal roof: 67%
  - White cement shingle: 77%
  - White EPDM and *Hypalon* products: 69 - 81%
- We identified the need for a consistent sample surface substrate for the comparative evaluation of paints and coatings.
- The potential success of spectrally selective roofing materials, with their reflectivity concentrated in the near infrared region, is compromised by the higher spectral energy content in the visible wavelengths of solar radiation.

Acknowledgements

This research has been funded by the Florida Energy Office in support of the Building Design Assistance Center. Their support is gratefully acknowledged. Philip Fairey and Subrato Chandra have provided a number of useful suggestions. The authors would also like to express their gratitude to Sara Bretz and Art Rosenfeld at Lawrence Berkeley Laboratories for sharing research information of mutual interest.

Special thanks to Ed Palko with *Owens Corning Fiberglas* and Bob Jenkins with *CertainTeed Corporation* for providing samples of asphalt shingles for testing. Dave Little at *ISP Minerals* supplied the premium white granule shingle for our evaluation. Bob Abernethy assisted with the preparation of asphalt shingles with the various coatings.

References

Akbari, H., Davis, S., Dorsano, S., Huang, J. and Winnett, S., 1992. Cooling Our Communities: A Guidebook on Tree Planting and Light-Colored Surfacing, 22P-2001, U.S. Environmental Protection Agency, Washington D.C.

Akbari, H., Rosenfeld, A.H. and Taha, H., 1990. "Summer Heat Islands, Urban Trees and White Surfaces," ASHRAE Transactions, Vol. 96, Pt. 1, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, GA.

Akbari, H., Huang, J., Sailor, D., Taha, H. and Bos, W., 1991. Monitoring Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces in the Sacramento Municipal Utility District Service Area, Interim Report to the California Institute for Energy Efficiency, Lawrence Berkeley Laboratory, Berkeley, CA.

Akbari, H., Taha, H. and Sailor, D., 1992. "Measured Savings in Air Conditioning from Shade Trees and White Surfaces," Proceedings of the 1992 ACEEE Summer Study on Energy Efficiency in Buildings, Vol. 9, p. 1, American Council for an Energy Efficient Economy, Washington D.C.

Anderson, R.W., 1989. "Radiation Control Coatings: An Under-utilized Energy Conservation Technology for Buildings," ASHRAE Transactions Vol. 95, Pt. 2.

Anderson, R.W., Yarbrough, D.W., Graves, R.S. and Wendt, R.L., 1991. "Preliminary Assessment of Radiation Control Coatings for Buildings," Insulation Materials: Testing and Applications, 2nd Volume, ASTM STP 1116, R.S. Graves and D.C. Wysocki, Eds., American Society for Testing and Materials, Philadelphia.

Bansal, N.K., Garg, S.N. and Kothari, S., 1992. "Effect of Exterior Surface Color on the Thermal Performance of Buildings," Building and Environment, Permagon Press, Vol. 27, No. 1, p. 31-37, Great Britain.

Boutwell C.J. and Salinas, Y., 1986. "Building for the Future- Phase I: An Energy Saving Materials Research Project," Mississippi Power Company, Rohm and Haas Company and the University of Southern Mississippi.

Brady, Jr., R.F. and Wake, L.V., 1992. "Principles and Formulations for Organic Coatings with Tailored Infrared Properties," Progress in Organic Coatings, No. 20, Elsevier Sequoia, Netherlands.

Bretz, S., Akbari, H., Rosenfeld, A. and Taha, H., 1992. Implementation of White Surfaces: Materials and Utility Programs, Heat Island Project, LBL 32467, Lawrence Berkeley Laboratory, Berkeley, CA.

Chandra, S. and Moalla, S., 1992. "Energy Savings from Industrialized Housing Construction Systems and Roofing Tiles," Proceedings of the 1992 Energy Efficient Building Association Conference, Raleigh, NC.

Chang, Te Chuan and Busching, H.W., 1983. Energy Savings Potential of Roofing Research, Oak Ridge National Laboratory, ORNL/SUB/82-22293/1, Oak Ridge, TN.

Fairey, P., 1986. "Radiant Energy Transfer and Radiant Barrier Systems in Buildings," Florida Solar Energy Center, FSEC-DN-6-86, Cape Canaveral, FL.

Givoni, B. 1976. Man, Climate and Architecture, Applied Science Publishers Ltd., London.

Givoni, B. and Hoffman, M.E., 1968. "Effect of Building Materials on Internal Tempera-tures," Research Report, Building Research Station, Technion Haifa, April, 1968.

Griggs, E.I, and Shipp, P.H., 1988. "The Impact of Surface Reflectance on the Thermal Performance of Roofs: An Experimental Study," ASHRAE Transactions, Vol. 94, Pt. 2, Atlanta, GA.

NRCA, 1993. "1991/1992 NRCA Market Study," National Roofing Contractor's Association, February.

Parker, D.S., Cummings, J.B., Sherwin, J.S., Stedman, T.C. and McIlvaine, J.E.R., 1993. Measured Air Conditioning Electricity Savings from Reflective Roof Coatings Applied to Florida Residences, FSEC-CR-596-93, Florida Solar Energy Center, Cape Canaveral, FL.

Reagan, J.A. and Acklam, D.M., 1979. "Solar Reflectivity of Common Building Materials and its Influences on the Roof Heat Gain of Typical Southwestern U.S. Residences," Energy and Buildings No. 2, Elsevier Sequoia, Netherlands.

Rosenfeld, A., Akbari, H., Taha, H. and Bretz, S., 1992. "Implementation of Light-Colored Surfaces: Profits for Utilities and Labels," Proceedings of the 1992 ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington D.C., Vol. 9, p. 141.

RSI, 1993. "Shedding light on color trends for residential roofs," Roofing, Siding and Insulation, March 1993.

Taha, H., Akbari, H., Rosenfeld, A.H. and Huang, J., 1988. "Residential Cooling Loads and the Urban Heat Island--the Effects of Albedo," Building and Environment, Vol 23, No. 4, Permagon Press, Great Britain.

Taha, H. Sailor, D. and Akbari, H., 1992. High Albedo Materials for Reducing Building Cooling Energy Use, Lawrence Berkeley Laboratory Report No. LBL-31721, Lawrence Berkeley Laboratory, Berkeley, CA.

Thekaekara, M.P., 1974. "Data on Incident Solar Energy," Supplement to the Proceedings of the 20th Annual Meeting of the Institute for Environmental Science, No. 21.

Wechsler, A.E. and Glaser, P.E., 1966. "Surface Characteristics Effect on Thermal Regime: Phase I," Special Report (88), U.S. Army, Cold Regions Research and Engineering Laboratory, Hanover, NH.

Submitted to:

Florida Energy Office
2555 Shumard Oak Blvd.
Tallahassee, FL 32399

1. Other testing on a number of other coatings products is contained in a study by Anderson et al. (1991).

2. Reagan and Acklam (1979) measured the solar reflectance of new unoiled and unpainted cedar shake wood shingles at 32%. Oiled shakes had a total solar reflectance of 28%.

On-line publications

Top of Article | Online Publication List