WHOLE HOUSE THERMAL PERFORMANCE OF ASPHALT SHINGLES EXPLOITING SPECIAL INFRARED REFLECTIVE PIGMENTS

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ABSTRACT

New “cool pigmented” colors that appear as dark colors in the visible spectrum but are highly reflective in the near-infrared portion of the electromagnetic spectrum can increase the infrared reflectance of building paints, thereby lowering the surface temperatures of the roof and exterior walls. These lower surface temperatures reduce the cooling-energy demand of the building and could increase the life of the roof product. However, determining the effects of climate and solar exposure on reflectance and color variability over time is of paramount importance for promoting the energy efficiency of such products and for accelerating their market penetration.

An experimental and analytical approach that combines field data, accelerated fluorescent light and xenon-arc exposure testing, and measurements from field demonstration homes in Redding California, is being used to quantify the total color change, durability, and potential utility savings for cool pigmented shingles as compared with conventional asphalt shingles.

KEYWORDS

Energy data, energy monitoring and analysis, data project case studies, government and utility energy policy, energy conservation, Rebuild America Program

INTRODUCTION

Dark colors are not necessarily heat absorbers provided that the colors are formulated with certain cool color pigments that are highly reflective in the near-infrared (NIR) portion of the solar spectrum. Brady and Wake (1992) found that 10-µm particles of TiO_2, when combined with colorants such as red and yellow iron oxides, phthalocyanine blue, and perylene black, could be used to formulate fairly dark colors with an NIR reflectance of 0.3 and higher. Researchers working with the Department of Defense added complex inorganic color pigments to paints used for military camouflage and matched the reflectance of background foliage in the visible and NIR spectra. The chlorophyll in plants strongly absorbs in the non-green parts of the visible spectrum, giving the leaf a dark green color with high reflectance elsewhere in the solar spectrum[1] (Kipling 1970). In the NIR the chlorophyll in foliage naturally boosts the reflectance of a plant leaf from 0.1 to about 0.9; this increased reflectance explains why a dark green leaf remains cool on a hot summer day.

Tailoring cool color pigments for a high NIR reflectance similar to that of chlorophyll provides an excellent opportunity for passive energy savings for exterior residential surfaces such as roofs exposed to the sun’s irradiance. Asphalt shingles are used for 84% of all steep-slope roofs nationally and for about 75% of all residential homes in the Pacific coast region (F. W. Dodge 2003). Therefore, improving the solar reflectance of asphalt shingles could have a significant impact on the electrical energy used for residential cooling. A black cool color pigment such as a mixture of chromic oxide (Cr_2O_3) and ferric oxide (Fe_2O_3) could increase the solar reflectance of a standard black pigment from 0.05 to 0.26 (Sliwinski, Pipoly, and Blonski 2001). Further details about identifying and characterizing dark yet highly reflective color pigments and calculating their potential energy benefits are discussed in Miller et al. (2004); Akbari et al. (2004); and Levinson, Berdahl, and Akbari (2004a–b).

Many utility boards, especially those in California, are keenly interested in knowing how much electrical energy could be saved if roofs with cool pigmented colors—sometimes referred to as cool roof color materials (CRCMs)—were adopted in the building market. Therefore, our primary objective is to demonstrate the thermal and potential economic benefits of CRCMs to utility boards that are considering offering rebates as well as to homeowners who are considering selection of shingles with infrared reflective (IRR) materials. For shingle manufacturers to adopt the technology, the color fastness of prototypes must be proven; thus, another objective of our research is demonstrate the fade resistance of IRR pigments.

[1]Except for some bands of radiative absorption by water.

FADE RESISTANCE OF ROOF PRODUCTS WITH COOL ROOF COLOR MATERIALS

If the color of a roof product does not remain fade resistant, the product will not be acceptable to the consumer. Industry judges fade resistance by measuring the spectral reflectance and transmittance of a painted or coated surface and converting the measures to color-scale values based on the procedures in ASTM E308-02 (ASTM 2001). The color-scale values for IRR pigments (L^*_{IRR}, a^*_{IRR}, and b^*_{IRR}) are compared with those for standard colors; and the color differences (ΔL, Δa, and Δb), which represent the luminance of color, are calculated from the following equations:

$\Delta L = L^*_{IRR} - L_{Standard}$,
where $\Delta L > 0$ is lighter and $\Delta L < 0$ is darker;

$\Delta a = a^*_{IRR} - a_{Standard}$,
where $\Delta a > 0$ is redder and $\Delta a < 0$ is greener; and

$\Delta b = b^*_{IRR} - b_{Standard}$,
where $\Delta b > 0$ is yellower and $\Delta b < 0$ is bluer.

Paint manufacturers have adopted a total color difference (ΔE) protocol to specify the permissible color change between a test specimen and a known standard. The total color difference value, described in ASTM D2244-02 (ASTM 2002a), is a method used to numerically identify variability in color over periods of time. Total color difference is calculated by the formula

$$\Delta E = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{1/2} . \qquad \text{Equation (1)}$$

Typically, ΔE changes of one unit or less are almost indistinguishable from the original color. Depending on the hue of color, a ΔE of 5 or less is considered very good.

ACCELERATED WEATHER TESTING

Roof products typically undergo degradation from oxidation reactions that result from any combination of the following processes: thermal degradation and photodegradation. Of these, photodegradation due to ultraviolet (UV) light and/or xenon-arc exposure are of primary importance for roofing systems. We conducted accelerated fluorescent and xenon-arc testing to document the photostability of conventional asphalt shingles and prototype shingles with IRR materials.

Materials and Methods

Sample Preparation and Weatherometer Protocol.

Asphalt shingle samples were cut to a size of 0.07 × 0.07 m (2.75 × 2.75 in.) from each of the different regions of the shingle. Identical shingle samples were mounted in xenon-arc and fluorescent UV light weatherometers and subjected to 5000 hours of accelerated weathering. The weatherometers maintained the temperature, moisture, and light. 3M conducted the xenon-arc accelerated weathering in accordance with ASTM G-155, using cycle 1 as described in Table X3.1, Common Exposure Conditions, of the G 155 standard (ASTM 2000). Shepherd Color Company conducted the fluorescent accelerated weathering in accordance with ASTM G154-04 using cycle 4 as described in Table X2.1, Common Exposure Conditions, of the G 154 standard (ASTM 2002b). A UVB-340 lamp was used for simulating direct solar UV radiation; this lamp has no UV output below 300 nm, which is the cutoff wavelength for terrestrial sunlight. Samples were measured for color and solar reflectance initially and then after every 1000 hours of exposure.

Solar Reflectance (SR) Instruments.

Solar reflectance was measured using a Devices and Services Solar Spectrum Reflectometer Model SSR-ER. The instrument uses a tungsten halogen lamp to diffusely illuminate the sample and measures the radiation reflected at a 20° angle from normal with four filtered detectors covering the solar spectrum. The relative response of the detectors to the light source is designed to approximate the solar spectrum. The four signals are weighted in appropriate proportions to yield the air-mass 1.5 near-normal-hemispherical solar reflectance, or more simply “solar reflectance.”

Color Measurements.

3M measured color using a Hunterlab Labscan XE model LSXE colorimeter set up with D65 illuminant and a 10° observer. The CIELab scale was used, and results were recorded as L^*_{IRR}, a^*_{IRR}, and b^*_{IRR} luminance measures. Shepherd Color Company used a MacBeth Color Eye (CE 7000) setup for CIELab scale readings with D65 illuminant and a 10° observer.

Results

UV Light Exposure Results.

The asphalt shingles with IRR pigments had an initial solar reflectance of about 0.26 and a thermal emittance of 0.90. Their counterparts with conventional color pigments had initial solar reflectance values ranging from 0.06 to 0.11 and a thermal emittance of 0.89. Exposure to fluorescent light did not adversely affect the solar reflectance of the IRR shingles; they maintained their reflectance just as well as the standard production shingles (Fig. 1). The IRR shingles coded A and E had a total color change (ΔE) of less than 1.5 after the 5000 hours of UV exposure (Fig. 2). By contrast, the conventionally pigmented counterparts had ΔE values that were 50% higher for the shingles coded A and 100% higher for E. The ΔE for the code C shingle with IRR pigments exceeded 2 after 1000 hours and then dropped below 1.0 after 5000 hours. The reason for this behavior is unknown; overall, however, the data clearly show that the IRR shingles perform just as well when subjected to direct solar UV radiation as standard products accepted on the open market. The IRR asphalt shingles do not lose solar reflectance, and they remain fade resistant.

A granule manufacturer performed weathering tests on roofing granules applied to an asphalt-coated panel at a south Florida exposure site using the ASTM G7 protocol (ASTM 1997) for natural exposure testing. The results, shown in Table 1, again show that cool color pigments (the Ferro pigments) perform as well as or even better than conventional pigments. The ΔE for the Ferro pigments was roughly half that measured for the standard production pigments, indicating that the cool color coatings have improved color retention over the 2–4 years of natural exposure testing.

Xenon-Arc Exposure Results.

Xenon-arc testing of the IRR asphalt shingles showed slight increases in solar reflectance through 3000 hours of exposure (Fig. 3). For example, solar reflectance increased from 0.27 to 0.29 before leveling at about 0.28 for the code A shingle with IRR pigments. The standard shingles also showed slight increases in solar reflectance as exposure progressed. It is evident that some oxidation of hydrocarbons in the shingles is occurring and possibly affecting surface reflectance in a positive manner. The total color change of the IRR shingles is comparable to that of their standard production counterparts, again demonstrating that the IRR shingles perform just as well (Fig. 4). The total color change, or ΔE, value for the IRR shingles is less than

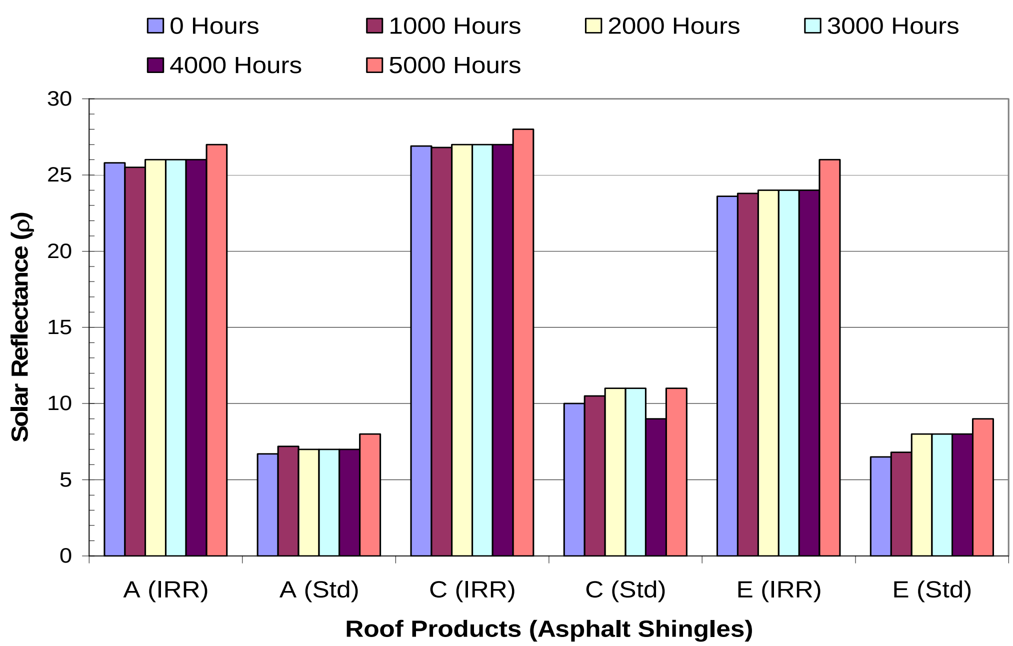

Figure 1. Solar reflectance of asphalt shingles under fluorescent UV light using the ASTM G154-04 protocol. (Data from Shepherd Color Company)

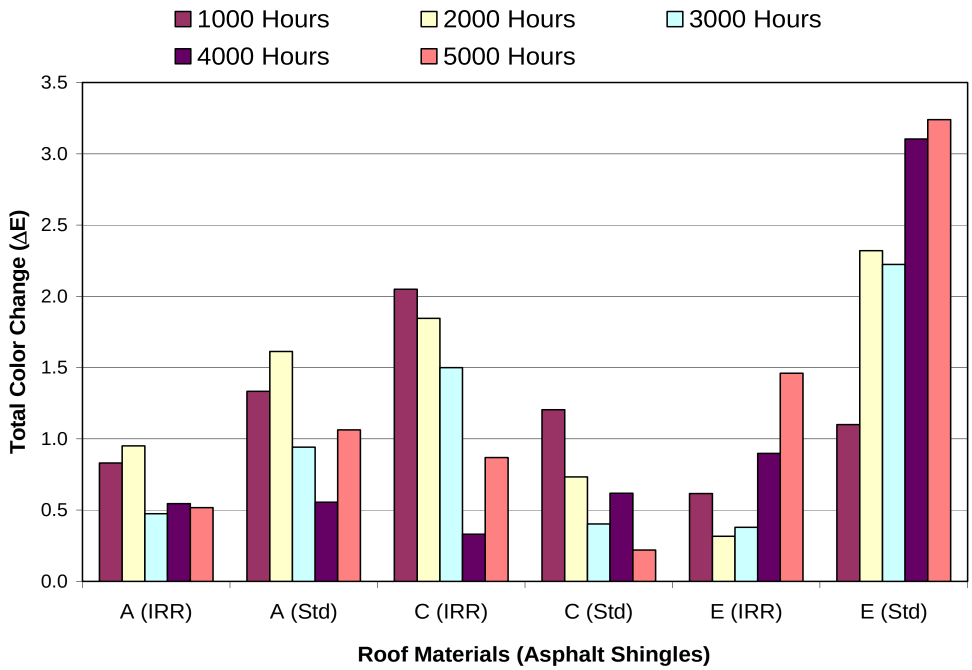

Figure 2. Total color change (ΔE) of asphalt shingles under fluorescent UV light using the ASTM G154-04 protocol. (Data from Shepherd Color Company)

Table 1. Granules exposed to natural sunlight in south Florida and painted with and without IRR coatings

Pigment	Exposure time (months)	Initial color of asphalt-coated panel			Color change after exposure (ΔE)
		L^*_{IRR}	a^*_{IRR}	b^*_{IRR}	
Conventional pigment					
Carbon black	18	22.0	0.4	-0.2	**2.4**
Black iron oxide	42.5	22.9	2.7	3.6	**1.6**
Cool color pigment					
Ferro V-778	58	26.0	2.1	2.6	**0.8**
Ferro O-1765B	23.5	22.7	1.5	0.7	**0.9**

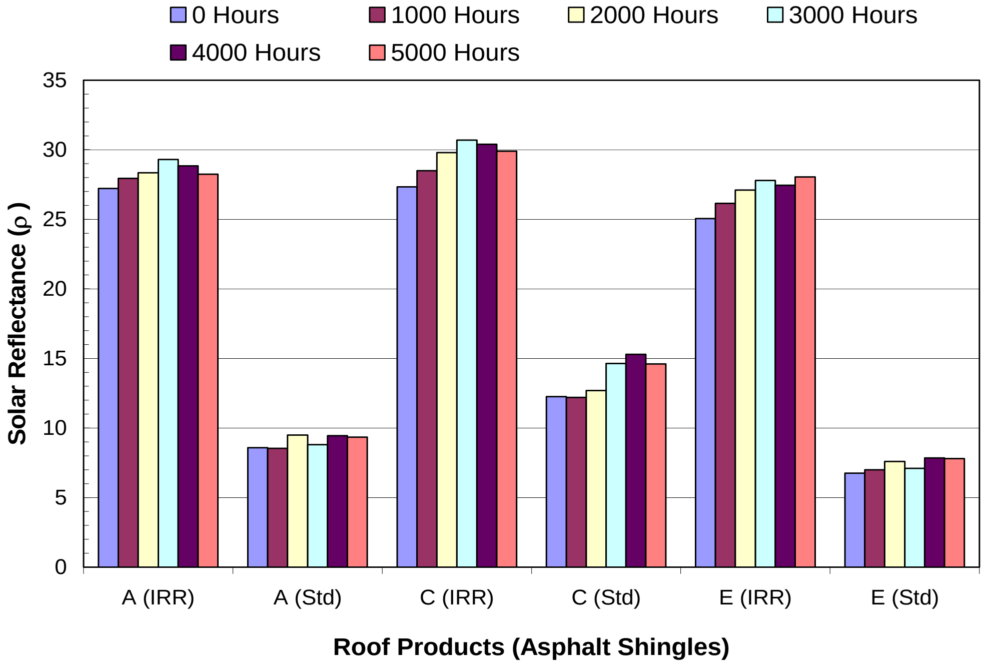

Figure 3. Solar reflectance of asphalt shingles under xenon-arc light using the ASTM G-155 protocol. (Data from 3M Company)

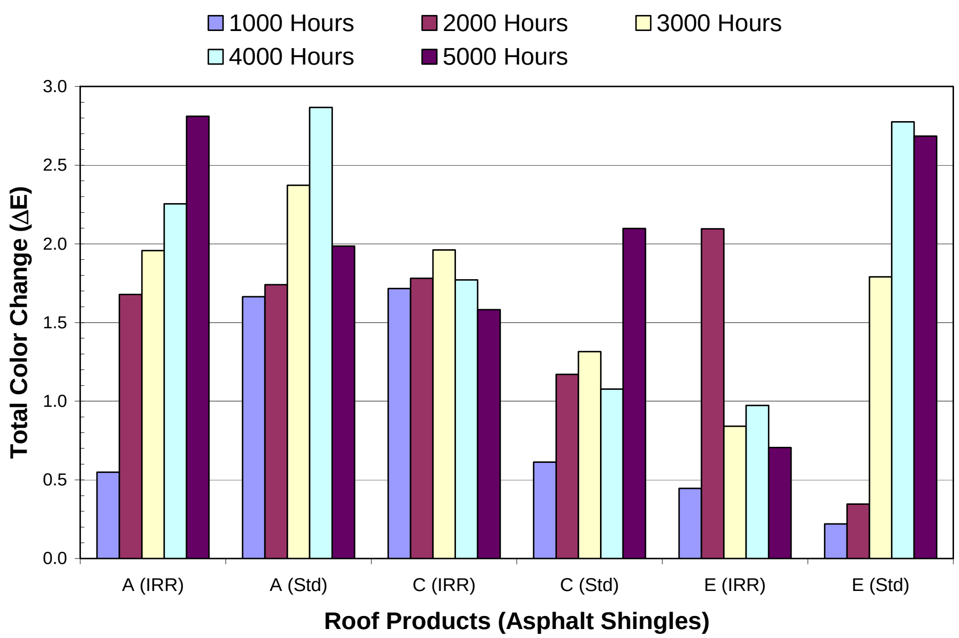

Figure 4. Total color change (ΔE) of asphalt shingles under xenon-arc light using the ASTM G-155 protocol. (Data from 3M Company)

3.0 after 5000 hours of exposure, which can be visually distinguished but is still considered good color fastness.

DEMONSTRATION HOME FIELD TESTING

Two new homes with identical footprints, layouts, and equipment design were equipped with asphalt shingle roofs with and without IRR pigments. The homes were built in Redding, California, by the firm Ochoa and Shehan, Inc. The Redding site was considered an excellent location for the field testing of asphalt shingles because high temperatures in the summer can be as much as 45°C (110°F) and winters typically have subfreezing temperatures. The two demonstration homes are on different cul-de-sacs but within about 100 yards of each other. Both have about the same azimuth orientation with respect to the sun, which allows direct comparison of the thermal performance of the two roof assemblies.

The residences are one-story ranch-style houses built on concrete slab. Each house has about 2400 square feet of floor space, and each uses two 3½-ton split-system air conditioners for comfort cooling. The attics for each home are ventilated by soffit and ridge vents. R-19 loose fill insulation was blown into the attic space, and the indoor air-handler and air-distribution ducting are located in the attic. All ducts were wrapped in R-5 insulation. Oriented strand board (OSB) decking facing the attic interior uses a radiant barrier, as required by the building codes for the county of Redding.

Elk Corporation donated its Weatherwood Prestique Cool Color and its conventional Weatherwood Prestique asphalt shingles for these field tests. The IRR shingle has a solar reflectance of 0.26 and a thermal emittance of 0.90. The conventional shingle has solar reflectance of 0.09 and thermal emittance of 0.89. The cool color shingles are advertised on Elk's web site[2] as the "first energy-efficient cool asphalt shingles offered in a palette of rich, organic colors." Elk offers a 40-year limited warranty with a limited wind warranty of up to 90 mph, and a UL Class "A" fire rating. The prototype shingles were developed in conjunction with 3M to meet the initial 0.25 solar reflectance specified by ENERGY STAR criteria.

<u>Instrumentation and Data Acquisition</u>

Instrumentation was added to the pair of demonstration homes to catalogue temperatures and heat flows across the roof and attic assembly and measure the relative humidity of the ambient air in the attic. Sensors were also installed in the living space to measure the indoor ambient return and supply air temperatures and the indoor relative humidity. Whole house power usage was obtained from the Redding utility with the permission of the homeowners. The power consumed by the condensing unit of each air conditioner was measured using watt-hour transducers.[3]

<u>Roof Deck and Attic Floor (Ceiling).</u>

Heat flux transducers (HFTs) were embedded in the roof decks and the attic floor to measure the heat flows crossing the decks and attic floor of each house. The roof decks are made of 5/8-in. OSB. Typical construction uses 15/32-in. OSB; however, the 5/8-in. OSB was selected because it is of sufficient thickness for embedding a 0.038-m- (0.15-in.-) thick HFT in the OSB without compromising the accuracy of the heat flow (Fig. 5).

We checked the thermal conductivity of 5/8-in.- and 1/4-in.-thick boards because OSB is made from various waste wood products and conductivity might therefore vary with thickness. A 0.61-m- (2-ft-) square section of 5/8-in. OSB was placed in a heat flux metering apparatus and calibrated to determine the thermal conductivity of the OSB. The top temperatures of the board were set at 7.2, 23.9, 37.8, and 48.9°C (45, 75, 100, and 120°F), which are typical temperatures observed by Parker, Sonne, and Sherwin (2002) for roof decks field tested in Ft. Myers, Florida. Results revealed that the thermal conductivity of OSB increased linearly with temperature. The thinner 1/4-in. OSB board was also tested and found to have a thermal conductance within ±0.5% of the measures obtained for the thicker 5/8-in. board. The thermal conductivity of the thinner board varied linearly and had the same slope as the thicker 5/8-in. board. Tests verified that the thinner board could be used as a cover plate to hold the heat flux transducer in place (Fig. 5) and would therefore not adversely affect the heat flow.

Shunting due to the differences in thermal conductance of the HFT and the OSB was also accounted for by calibrating the HFT in a 0.61 × 0.61 m (2 × 2 ft) guard of 5/8-in.-thick OSB using the ASTM C518 protocol (ASTM 1998). Calibration showed a slight but linear drop in sensitivity as the temperature of the OSB was increased from 4.4 to 48.9°C (40° to 120°F). The guard became a portion of a sandwich panel equipped with copper/constantan

[2]http://www.elkcorp.com/homeowners/products/shingles_prestique_ccs.cfm

[3]The power of the indoor blower was not measured by the transducers.

Figure 5. Heat flux transducer embedded in OSB guard and used to measure heat flow crossing roof decks of the demonstration homes with asphalt shingle roofs.

thermocouples and the HFT. Once calibrated, the sandwich panels were shipped to the builders and installed in the adjacent roof decks of each demonstration home. The sandwich panel was made of the same material as the deck and was also the same thickness.

While the roof products were being installed, the thermocouples attached to the sandwich panels were epoxy-glued to the roof surface, taped to the topside of the deck, placed adjacent to the HFT embedded in the OSB, and taped to the underside of the OSB deck facing the interior of the attic. The thinner 1/4-in. board was attached to the underside of the deck to provide access for future maintenance (Fig. 5).

A similar procedure was used for setup of the HFT measuring the heat flow crossing the attic floor and entering the conditioned space. Here, however, we taped an HFT in the center of a 0.61 × 0.61 m (2 × 2 ft) piece of gypsum board, covered the device with R-19 batt insulation, and proceeded to calibrate the transducer. In the field we simply taped the HFT to ceiling drywall and attached a thermocouple adjacent to the HFT. Later, after insulation was blown into the attic, we placed a thermocouple approximately at the top surface of the blown insulation.

Weather Data.

Pyranometers were placed on adjacent sloped roofs of each home for measuring the morning and afternoon solar irradiance. These measures helped prove that, for instance, the west-facing roofs for the pair of homes had the same intensity of solar flux. The instruments also indicated the daylight hours and displayed peak irradiance with time of day. A thermocouple for measuring the outdoor air temperature was placed underneath the roof soffit, where it was shaded and sheltered from rain. All other weather data were gleaned from the California Irrigation Management Information System (CIMIS); CIMIS provides current weather data from computerized weather stations acquiring hourly, daily, weekly, and/or monthly solar irradiance, ambient air temperature and relative humidity as well as wind speed, wind direction, and precipitation.[4]

Power Measurements.

Watt-hour transducers (Wattnode Model WNA-1P-240-P) measured the electrical energy consumed by each outdoor condenser unit. The transducers with current transducers were installed in the power panel of each home.

Data Acquisition System.

Campbell Scientific micro-loggers were used for remote acquisition and recording of field data. Salient features of the micro loggers are provided in Table 2. The loggers were equipped with 4 MB of memory, a 25-channel multiplexer for thermocouples, a rechargeable battery, a 115 Vac-to-24 Vdc transformer, a modem, a modem surge protector, a weatherproof enclosure and associated cables.

The mirco-logger was programmed to scan every 30 seconds and reduce analog signals to the engineering units. Averages of the reduced data were

[4]Web site: http://www.cimis.water.ca.gov/.

Table 2. Salient features of Campbell scientific data loggers

Item	Item description	CSI part No.
1	CR-23x data logger with 4-MB memory	CR10X-2M
2	Array-based operating system for CR-23X-4m	9801
3	Thermocouple reference thermistor for CR23X wiring panel	CR10XTCR
4	12-V power supply with charging regulator and rechargeable battery	PS100
5	18-V, 1.2-A wall charger, 6 ft	9591
6	16-channel (4-wire) or 32-channel (2-wire) relay multiplexer	AM16/32
7	25-channel solid-state multiplexer for thermocouples	AM25T
8	Data cable, two peripheral connector cables for data logger, 2 ft	SC12
9	8-channel switch closure module	SDM-SW8A
10	Telephone modem	COM210
11	Phone modem surge protector	6362
12	Enclosure 16/18, weather-resistant	15873

written electronically to an open file every 15 min. The averages were calculated over the 15-min interval and are not running averages; they are reset after each 15-min interval. The electronic format is comma-delimited for direct access by spreadsheet programs. Data files consist of one full week of data containing 672 rows of averaged measurements representing the instrument measurements written every 15 min over the 168 hours of a week. The micro-logger automatically closes the existing file and opens a new data file every Friday at midnight for recording the next week of data. A dedicated desktop computer calls the micro-logger and acquires the previous week of data over a modem connected to a dedicated phone line.

Demonstration Results

The attics and roof decks of each demonstration home were instrumented to document the immediate effects of IRR pigments on the deck and attic air temperatures and the heat flows crossing the roof deck. Our intent was to demonstrate typical summer performance of IRR shingles and to collect data useful for formulating and validating computer codes capable of calculating the heat transfer occurring within the attic. Once validated, these attic simulations can be coupled to whole-house building models for simulating and predicting local, state, and national energy savings afforded by roofs with IRR shingles. The following sections describe our findings about temperature and heat flow results for the roofs and attics of the demonstration home and cooling energy savings.

Roof Temperature and Heat Flow.

July and August ambient air temperatures in Redding often exceed 45°C (110°F). Redding field data for August 2005 show that the conventional shingles on the demonstration homes experienced peak temperatures of about 73°C (163°F) as compared with peak temperatures of about 70°C (158°F) for the IRR shingles (Fig. 6). Similar drops were observed in the attic air temperature (Fig. 6).

The reduction in peak temperatures for the cool shingles has potential benefits for improving the chemical and flexural properties of the shingles. Terrenzio et al. (2002) and Shiao et al. (ASTM 2003) showed that heating of asphalt shingles promotes the vaporization and diffusion of oils from the asphalt, with the subsequent migration of oxygen into the asphalt. Terrenzio noted that as aging progresses, the stiffness of the asphalt increases. Therefore, IRR pigments may help increase the service life of shingles, although there is no definitive data that correlate service life to stiffness of the shingle.

The 3°C (5°F) drop in surface temperature in turn resulted in a reduction in the heat flow that was penetrating the west-facing roof for the pair of homes. A sustained and consistently lower heat flux occurs when IRR pigments are applied to the shingles (Fig. 7). The IRR shingles had about a 30% lower heat flux than the conventionally pigmented shingle over the daylight hours during a week in August 2005. The reduced heat flow lessens the burden on the air-conditioning system and should lead to a reduction in electrical energy consumed for comfort cooling.

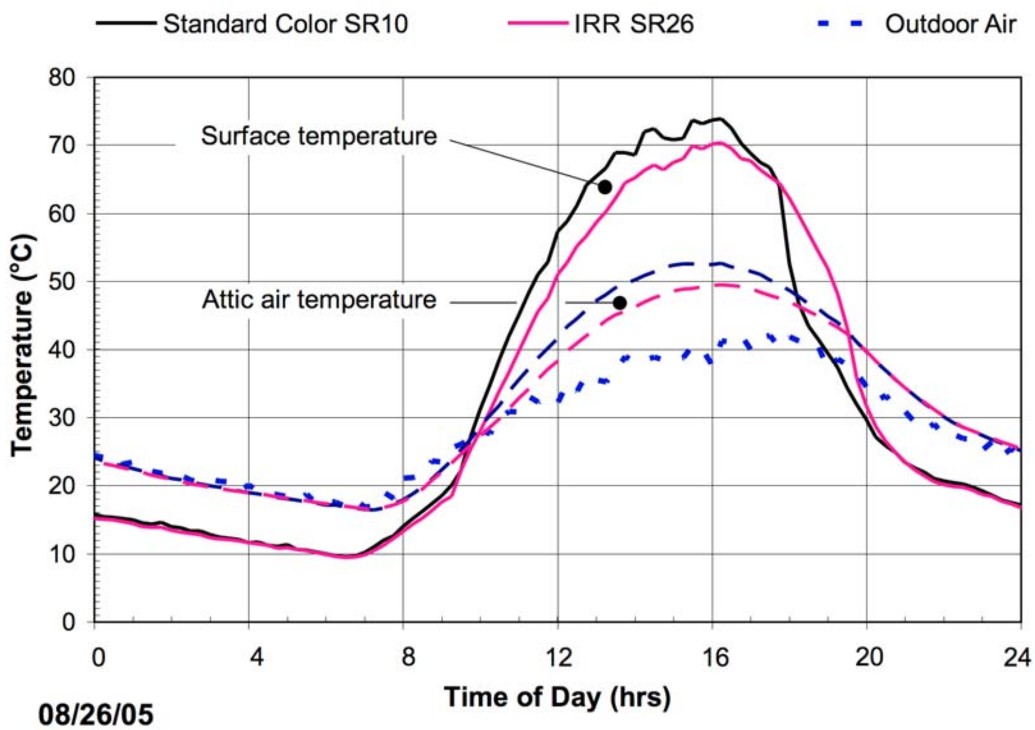

Figure 6. Surface (solid lines) and attic air (dashed lines) temperatures for the conventional and IRR asphalt shingle roofs: week of data in August 2005.

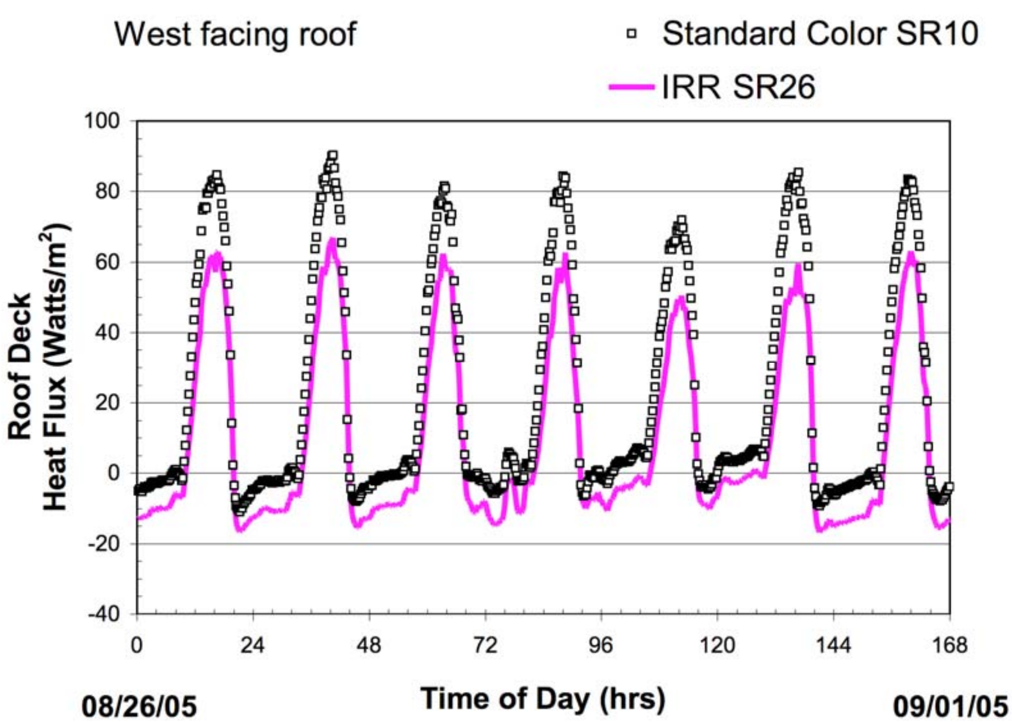

Figure 7. Heat flows penetrating the roof deck for the demonstration houses with conventional and IRR asphalt shingle roofs.

Cooling Energy Savings.

The principal focus of the field demonstrations was on collecting attic and roof data to prove the thermal benefits of the cool pigment technology. But the experiments also included measurement of power use and of air-conditioning supply and return air temperatures in an effort to estimate annual savings independently of the effects of occupancy habits or, put differently, corrected for the effects of occupants.

Redding Electric provided the 2005 summer revenue meter readings for the pair of demonstration houses (Fig. 8). The summer 2005 electrical use for the house with IRR shingles was 67% higher than that of the house with conventional shingles. Discussions with the homeowner of the house with conventional shingles revealed, however, that this house was used as a second residence and was not consistently occupied during the summer nor was the thermostat maintained at 22°C (72°F). In contrast, the house with a IRR shingle roof was occupied throughout the summer.

To correct for these differences in occupancy habits, power measurements were reduced to daily electrical energy consumptions. The electrical usage of the air conditioners was plotted against the daily average outside air-to-indoor air temperature difference. Regression analysis of the reduced data helped to remove the effects of different thermostat settings and occupancy habits.

When the outdoor air and return air temperatures are about the same, the regression lines for the pair of houses nearly intersect (Fig. 9). This simply means that no cooling is required by the houses, and there is no air conditioner usage. However, as the temperature difference from the outdoor air to the home's return air increases, the cooling savings also increase for the pair of shingle demonstrations (Fig. 9). At an outdoor ambient air-to-indoor air temperature difference of 10°C (18°F) [about 32.2°C (90°F) outdoor air temperature], the house with IRR

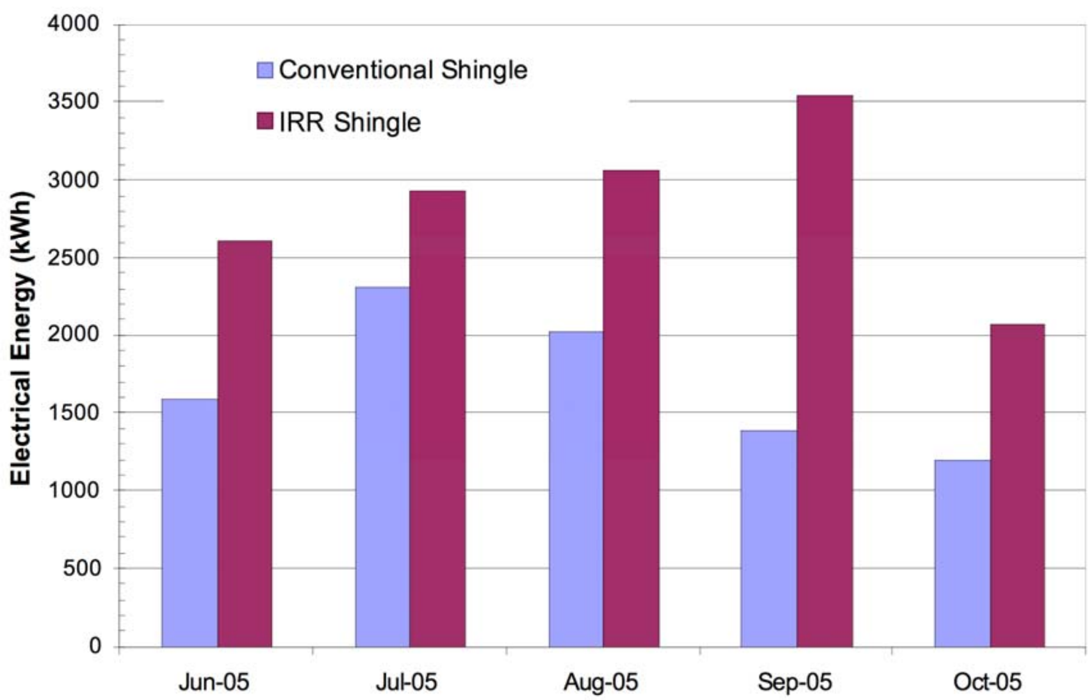

Figure 8. Monthly energy use (revenue meter readings) for demonstration houses in Redding, California.

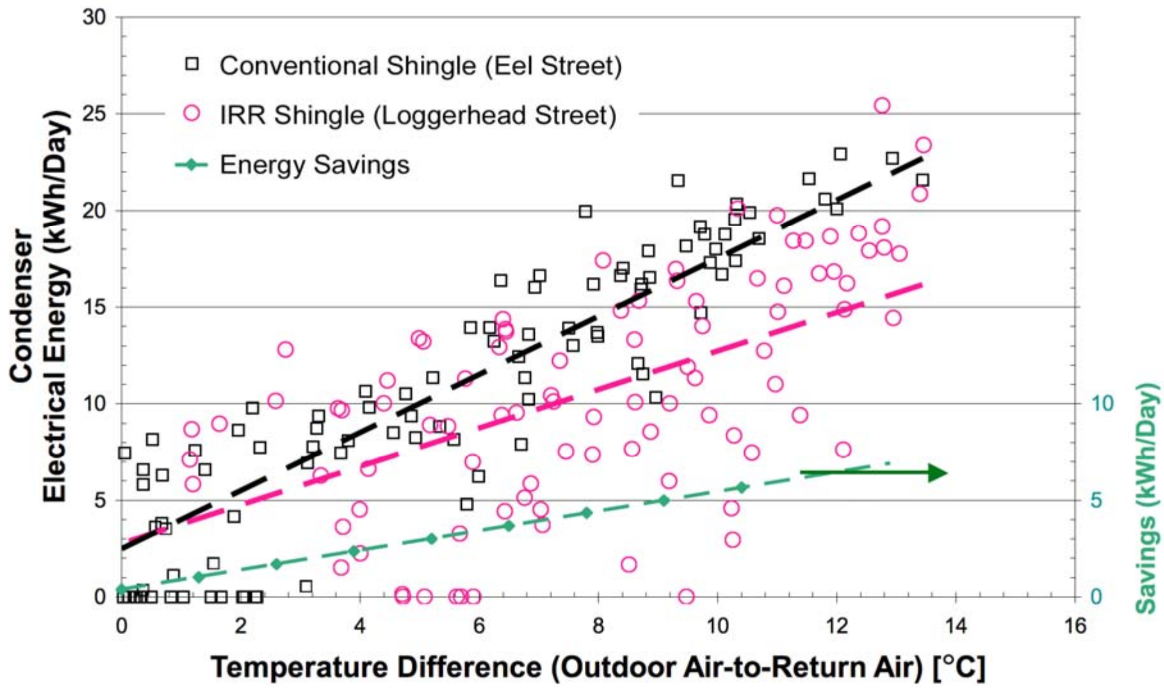

Figure 9. Air-conditioning cooling energy usage and savings, measured during the daylight hours (May through July 2005) for demonstration houses with conventional and IRR asphalt shingle roofs. Indoor blower power is not included.

asphalt shingles uses 6.3 kWh per day less electricity[5] than the house with conventional shingles. The cool pigments are therefore providing savings of roughly 0.90 kWh per day per ton of cooling capacity. The whole house electrical consumption for the home with IRR shingles (which was more fully utilized than the home with conventional shingles) was obtained from Redding Electric's revenue meters and averaged over the summer months (June through October 2005) at about 92 kWh per day. Therefore, whole house power drops about 7% due to the use of IRR materials in asphalt shingles.

It is interesting to note that higher outdoor air temperatures yield greater energy savings for the air conditioners operating in the houses with IRR roofs. The trend is slight yet could be important in terms of the time-dependent valuation of energy, which places a premium cost on energy consumed during the hottest portion of the day.

The new asphalt shingles showcased in Redding have resulted in the demonstrable reduction of heat buildup in the roof deck through the use of IRR pigments. John McCaskill, product brand manager for Elk Corporation, reports that the additional cost for the finished product of approximately 25¢ per square foot makes this product a reasonable alternative to radiant barriers for the reduction of cooling load. The combination of the cost-effectiveness of IRR asphalt shingles with the potential reduction of urban heat island effects provides a mainstream solution for the residential reroofing market as well as new construction. Elk now offers four "cool" shingle colors across two product lines.

CONCLUSIONS

In accelerated weathering tests, xenon-arc and fluorescent light exposures were conducted to judge the effectiveness of IRR pigments in asphalt shingle roof products. Test results showed that new cool pigmented asphalt shingle roofs maintain their solar reflectance as well as their standard production counterparts. Total color change is reduced or is at least similar to that of conventional shingles, meaning that the new IRR products have similar if not improved fade resistance.

When asphalt shingles are heated, they can undergo chemical changes and changes in visible and solar reflectance. Elevated temperature—for

[5]Indoor blower energy is not included in the 6.3 kWh savings.

example, as provided by solar absorption in dark materials—can accelerate physical changes and hasten the diffusion of low-molecular-weight components. Since photodegradation is a complex process that depends upon material type, including additives and impurities, it is difficult to generalize about how photodegradation should be altered by increased temperatures. Intuitively, one would expect that higher temperatures would assist photodegradation. However, photodegradation of the asphalt shingle products was not observed for these accelerated exposure test results. The solar reflectance of the asphalt shingles with and without IRR pigments showed slight increases, with larger increases in reflectance for the cool pigmented shingles. Total color change among IRR and conventional pigmented shingles was very similar, indicating once again that the new IRR products are market ready.

Thermal performance data proved the superior performance of IRR asphalt shingle roof products. The cooler surface temperatures resulting from use of these products causes average heat flows through the roof deck to drop by 30% as compared with flows for roofs with conventional shingles. The resulting decrease in heat penetrating the conditioned space results in both cooling and whole house energy savings. The asphalt shingle demonstration showed savings of about 7% in whole house energy consumed by the home with IRR shingles and savings of about 0.90 kWh per day of electrical energy per ton of air-conditioning capacity.

The United States is a nation of about 102 million residential homes and sees a growth of more than 1 million new homes annually (Kelso and Kinzey 2000). Electrically driven air-conditioning is used in about 66 million of these residences. The ability to meet peak electricity demand in the future is one of the primary issues confronting public utility companies. This is especially true in California, which has about 180,000 new houses built each year.[6] California also has 12 million existing homes, of which 6.8 million are single-family detached houses (State of California 2000). In California, residential air-conditioning loads represent almost 14% of the summer peak demand, the equivalent of over 7,000 MW of peak capacity during a hot California summer day.

The use of IRR pigments for shingles provides an opportunity both in California and in the southern United States to significantly improve energy savings in residential housing both for new housing and for existing homes, where asphalt shingles are typically replaced every 15 years. “Cool roofs” can provide a part (roughly 7%) of the solution to California’s dilemma without introducing new complexity (no moving parts). Cool asphalt shingle roofs can help reduce peak demand load and reduce the need to acquire additional capacity. Such products have recently become available to a limited extent, but the full value in peak demand reduction can be achieved only by the additive effect resulting from the widespread use of cool roofs. Governmental support in the form of tax credits for all ENERGY STAR–compliant roofs and homeowner rebates from utility companies are now needed to help ensure that the benefits of such energy saving measures are fully realized.

[6] Based on the California-to-U.S. population proportion of roughly 18%.

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