ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

September 24, 2003

To: Chris Scruton
Project Manager
California Energy Commission

From: Hashem Akbari

Subject: Cool Roof Colored Materials—Minutes of September 11, 2003 PAC Meeting

CC: Berdahl, P. (LBNL); Desjarlais, A. (ORNL); Jenkins, N. (CEC); Levinson, R. (LBNL); Miller, W. (ORNL); Wiel, S. (LBNL)

**Note:** *Due to a technical problem (on our site), we were not able to patch in two partners that were on the telephone. We decided to circulate the draft of the minutes of the PAC meeting and ask for their input.*

On September 11, 2003 from 9 am to 11:30 am, the LBNL/ORNL project staff and the CEC project manager held at LBNL their third Project Advisory Committee meeting for CEC's project on Development of Cool Colored Roofing Materials. Present at the meeting were the LBNL/ORNL project team, the CEC project manager, the manager of the CEC PIER buildings program, members of the PAC, and representatives from twelve industrial partners. The meeting participants are listed in Attachment 1. The agenda for the meeting is presented in Attachment 2. Attachments 3, 4, and 5 list the LBNL and ORNL project team members, the industrial partners to the project, and the members of the PAC, respectively. Attachment 6 shows the presentation materials.

## I. Introduction

A. The CEC Project Manger, Chris Scruton, opened the meeting with some comments on the objectives of the project and the reasons to have PAC meetings (Slides 1-3). The meeting participants (PAC members, project team members, and industrial partners) introduced themselves and stated their specific interests in the project.

B. Scruton also introduced and welcomed the new industrial partners of the project (Slide 4).

C. Wiel (Project Director) introduced the research team at LBNL and ORNL (Slide 5).

D. Wiel outlined the technical tasks to be discussed at the meeting (Slide 6). He mentioned that although "technology transfer" is an integral part of our overall approach, we would not discuss it explicitly at the meeting. Then he introduced Akbari to present Tasks 2.4 and 2.5.

## II. Project Objectives and Technical Tasks

**A. Task 2.4: Development of Cool-Colored Coatings.** Akbari briefly reviewed the objectives of Task 2.4 "Development of Cool Colored Coatings" and the three Subtasks of 2.4.1, 2.4.2, and 2.4.3 (Slide 7). He mentioned that Subtask 2.4.3 would be only briefly discussed at the meeting. Then he briefly reviewed the status of Subtasks 2.4.1 (Slides 8-9). It was asked whether in the characterization of pigments we will also address thermal emissivity. Akbari responded that the primary focus of the project is development of cool-colored materials. With that focus, we mostly study on solar reflectance of materials. We also measure their thermal emittance. Akbari then asked Levinson to present the details of Subtask 2.4.1.

1. *Subtask 2.4.1: Identify and Characterize Pigments with High Solar Reflectance* (Slides 9–15). Levinson mentioned that 83 single-pigmented have been measured, characterized, and their Kubelka-Munk absorption and scattering coefficients calculated. Reflectance measurements have been made over white, black, and void (black-body) backgrounds. We have also prepared and measured the optical properties of 116 tints (mixtures of colors with white). He

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discussed the activities undertaken under this subtask and showed an example of the measured and computed optical characteristics of a Chromium Iron Oxide IR-reflecting black pigment. He also discussed the adaptation (and refinement) of the Kubelka-Munk (K-M) theory and presented and example of calculated absorption (K) and scattering (S) coefficients. He mentioned that the LBNL K-M model has been completed. Then he showed a summary of pigment samples with "cool" and "hot" characteristics. He concluded his comments by outlining the planned activities for this subtask for the reminder of the project. Project team members and the industrial partners made various clarifying comments regarding which attributes are beneficial and which are detrimental and about the desired thickness of coatings.

**Action Items:**

- None.

2. *Subtask 2.4.2: Develop a Computer Program for Optimal Design of Cool Coatings* (Slides 16-17). Levinson continued with the brief review of the activities for development of the software (algorithm) for optimal design of cool coatings. The algorithm will use the data developed in subtask 2.4.1 and will allow us to estimate coating reflectance from pigment properties (absorption and scattering) and film geometry (mixing and layering). There were no comments and questions on this subtask.

   **Action Items:**

   - None.

3. *Subtask 2.4.3: Cool-colored Material Database* (Slides 18-19). Levinson continued with a brief introduction of the preliminary design of the database. The current database has data on 83 single-pigment paints. Data for each paint include spectral solar reflectance and transmittance; pigment chemistry, name, and measured film thickness; computed K-M absorption and scattering coefficients; and many ancillary values. The suggested format for data transfer is an archive of tab-delimited text files, one file per paint.

   There were several questions on whether the database would include all pigment characteristics such as durability, toxicity, environmental effects, cost, economic analysis, etc. Currently the information in the database is limited to optical characteristics mentioned in Task 2.4.3. The database can easily be expanded, provided sufficient funding for the effort is available.

   **Action Items:**

   - None.

**B. Task 2.5: Development of Prototype Cool-Colored Roofing Materials** (Slide 20). Akbari reiterated that the objective of Task 2.5 is to review the current methods of application of color pigments on roofing materials and to design and propose innovative engineering methods to achieve superior solar reflectance that are compatible with existing production processes.

**1.** *Subtask 2.5.1: Review of Roofing Materials Manufacturing Methods* (Slides 21–33). Akbari mentioned that the work on this subtask was basically completed by June 1, 2003. A draft report summarizing the results of literature review and visits to several roof materials manufacturing plants (asphalt shingles, metal roofing, roofing granules, and clay roof tiles) has been prepared and is available on our Cool Roof web site. Akbari mentioned that we would like to also visit a cement roof tile plant and amend our report to include this roofing material.

*Post-PAC- Meeting comment added by Steve Harris:*
The Cedar Shake and Shingle Bureau would like to request that you visit a Cedar shake and shingle fire treatment plant to review and develop a method of application of cool color pigments on cedar shakes and shingles which would be compatible with existing production processes.

**Action Items:**

- Jerry Vandewater of Monier Lifetile will work with Akbari to schedule visiting a cement roof tile plant.
- *Post-PAC- Meeting Action Item:* Steve Harris will work with Akbari to schedule visiting a Cedar shake and shingle fire treatment plant.

**2.** *Subtask 2.5.2: Design Innovative Methods for Application of Cool Coatings to Roofing Materials* (Slides 34–41). Berdahl briefly discussed a few promising pigments that can be applied with a two-layered technique for development of cool roofs. We have started sharing our pigment data with manufacturers. We will be coordinating with granule, shingle, and tile manufacturers to produce prototype cool samples. There were some questions regarding the applicability of the layered technique for production of cool materials. Our industrial partners responded that the technique was certainly feasible.

**Action Items:**

- During the months of September and October (2003), Akbari will coordinate independent conference calls between the project team and each manufactures.

**C. Task 2.6: Field Testing and Product Useful Life Testing** (Slides 42). Miller started discussion of the progress on this task by briefly reviewing the task objectives.

**1.** *Task 2.6.1: Building Energy Use Measurements at California Demonstration Sites* (Slides 43-48). Miller stated that the construction of four houses at the Mike Evan's development is in progress. These four houses will be used for demonstration of cool metal roofs and cement roof tiles. Our industrial partners mentioned collaboration between Ferro and MonierLife Roof tile for development of cool color cement tiles. He also briefly discussed the instrumentation and data collection system on each demonstration house. There were comments that measured energy savings data are needed to get manufacturers excited about the cool-colored roofing materials. Also, we should try to characterize the effect of the occupancy on the savings.

*Post-PAC- Meeting comment added by Steve Harris:*
The Cedar Shake and Shingle Bureau would like to be involved in the Building Energy Use Measurements at California Demonstration Sites by supplying product for two houses (cool colored and comparison). I believe the next opportunity for this will be in the spring.

Miller and Akbari: Out of the six demonstration houses, four have been assigned to metal roofs and tile roofs. The other two houses are reserved for demonstration of asphalt shingles. We will discuss with the CEC project manager the potential of expanding the demonstration sites to include other roofing materials.

## Action Items:

- *Post-PAC- Meeting Action Item:* Miller and Akbari will contact Harris and discuss options for two additional demonstration homes with cedar shake roofs in Sacramento, CA.

**2.** *Subtask 2.6.2: Materials Testing at Weathering Farms in California* (Slides 49-54). At the onset of the discussion, Miller announced that all samples have been installed at the seven weathering farms in California. He also discussed a protocol for sending the samples back to ORNL at regular intervals for re-measurement of solar reflectance and thermal emittance.

*Post-PAC- Meeting comment added by Steve Harris:*
The Cedar Shake and Shingle Bureau would like to provide samples for the Weathering Farms in California.

**Action Items:**

- *Post-PAC- Meeting Action Item:* The exposure racks have room available for cedar shake samples. Miller will provide Harris with the pertinent information for making the samples.

**3.** *Subtask 2.6.3: Steep-Slope Assembly Testing at ORNL* (Slides 55-60). Miller reviewed the status of the current and future plans for testing of the roofing materials at the Envelope Systems Research Apparatus (ESRA) at ORNL. He showed the results from a CFD model simulating natural air ventilation underneath roof tiles, potentially leading to a lower roof tile temperature during the hot days. There were question regarding measuring techniques for natural airflow underneath the roof tiles.

**Action Items:**

- Miller to replace metal roof samples with roof tile samples.

## III. Summary Comments from PAC Members

At the conclusion of the meeting, each PAC member and participants provided some summary comments. Noah Horowitz (NRDC) stated that actual energy saving measurement and comparison with simulations and predictions are needed. Kathy Diehl (EPA) indicated that it is important to have estimates of savings for occupied buildings. Chris Scruton (CEC) asked on how much of an effect occupants have on the attic temperature. Keith Tellman (Elk Corp) responded that the effect may be large.

The open discussions continued by Todd Alwart (DuPont) raising concern that the customers need incentives to adopt to the new technology. Krishna Srinivasan (GAF) also mentioned that market demand for cool materials is low. About 2/3 of the roofing market in commercial sector still uses black materials. Kathy Diehl asked how effectiveness of consumer credits and rebates. Nancy Jenkins (CEC) mentioned that CEC is working closely with utilities for coordination of R&D on emerging technologies (including cool roof). Nancy Jenkins (CEC) mentioned that the Commission is working closely with investor owned utilities in California to coordinate R&D and deployment of emerging technologies. Through the Emerging Technology Coordinating Council, the Commission is able to introduce newly developed technologies such as cool roofs to the utilities for consideration in further demonstrations and possible incentives through the utility emerging technology and energy efficiency programs. Yoshi Suzuki (MCA) mentioned that the current standards and credits are for low-sloped roofs; we need to develop standards for sloped roofs. Nancy Jenkins responded that there are not enough cool low-sloped products in the market to warrant updating California Title 24 Standards. Noah Horowitz mentioned perhaps we could update the standards for 2008 cycle.

The discussion of energy savings potential continued with Chris Scruton mentioning that the energy savings from cool-colored roofs (in addition to other energy efficiency measures) may eliminate the need for residential air-conditioning in some California transitional climates. Krishna Srinivasan asked what is the estimated saving in a typical house. Akbari responded about $100 per year in a 2000 $ft^2$ house in hot climates. Todd Alwart and a few others mentioned that this information should be shared with contractors. Tom Bollnow (NRCA) mentioned that the energy savings may not be sufficient incentives for individual homeowners to use cool colored roofing materials; we should somehow change the market so that cool materials will be the only materials available in the market. Stephen Wiel mentioned perhaps the use of labeling would help the market penetration.

Kathy Diehl also mentioned that we should also provide the bigger picture (i.e., heat island reduction, improved air-quality, longer lasting materials) to the customers. Mike Desouto (GAF) pointed out that durability measurement of cool materials is indeed needed. He also mentioned that it is hard to develop cool granulated surfaces. Ming Shiao (CertainTeed) mentioned that we still have a long way to go in improving the cool-colored technology for roofing materials.

In the conclusion of the discussions, Noah Horowitz mentioned the glaring absence of California electric utilities at the PAC.

The summary comments by the PAC members included:

- The PAC members were very pleased with the success of the project and the amount of the work completed to date. They mentioned that the project is on the right track and expressed satisfaction with the direction and accomplishments of the project to date.

  **Action Items:**

  - Akbari to contact PG&E and SCE and invite them to the PAC.

IV. **Schedules of PAC Meetings and Concluding Remarks (Slides 61-62).** The schedules of all future PAC meetings were presented. The next meeting is scheduled for Thursday, March 4, 2004 to be held in Sacramento. All materials related to the project will be posted to http://CoolColors.LBL.gov.

V. **Adjourn.** The PAC meeting adjourned at 11:45 am.

*Attachment 1.*

# Attendance, Cool Colored Roof PAC Meeting
# LBNL, Berkeley, CA
# September 11, 2003

| Name | Affiliation | Phone Number |
|---|---|---|
| Akbari, Hashem | Lawrence Berkeley National Laboratory | 510-486-4287 |
| Alwart, Todd | DuPont Titanium Technologies | |
| Berdahl, Paul | Lawrence Berkeley National Laboratory | 510-486-5278 |
| Bollnow, Tom | National Roofing Contractors Association | 847-299-9070 |
| Desjarlais, André | Oak Ridge National Laboratory | 865-574-0022 |
| Desouto, Mike | GAF Materials Corporation | 508 668-4128 |
| Diehl, Kathy | EPA San Francisco Office | 415 972-3996 |
| Gross, Chris | 3M Minerals | 651-736-4379 |
| Higgs, Darrel | Owens Corning | 419-248-7060 |
| Harris, Steven* | Quality Auditing Institute | 604-828-7283 |
| Horowitz, Noah | NRDC/CRRC | 415-777-0220 |
| Jenkins, Nancy | California Energy Commission PIER | 916-654-4739 |
| Joyce, Ivan | Ferro Corp. | |
| Keating, Jay | Owens Corning | |
| Levinson, Ronnen | Lawrence Berkeley National Laboratory | 510-486-7494 |
| Miller, William A. | Oak Ridge National Laboratory | 865-574-2013 |
| Scruton, Chris | California Energy Commission PIER | 916-355-0948 |
| Shiao, Ming | CertainTeed | 610-341-6431 |
| Srinivasan, Krishna | GAF | 973-628-3000 |
| Suzuki, Yoshi | MCA Clay Tile | 800-736-6221 |
| Tellman, Keith | Elk Corporation | 972-872-2284 |
| Scichili, Robert* | BASF Corporation | 972-234-0180 |
| Vandewater, Jerry | Monier Lifetile | 805-379-2636 |
| Wiel, Stephen | Lawrence Berkeley National Laboratory | 510-486-5396 |

* Joined the PAC through conference call.

*Attachment 2.*

*Agenda*

# Development of Cool Colored Roofing Materials

**Project Advisory Committee Meeting**

9 am to 11:30 am (PST)

Thursday, September 11, 2003

**Room 4133, LBNL, Berkeley, CA**

## I. Introduction (9:00-9:20)

A. Opening remarks and the objectives of the PAC meetings (CEC Project Manager: Chris Scruton)
B. Introduction of the new industrial partners (CEC Project Manager: Chris Scruton)
C. Introduction of the ORNL and LBNL project staff (Project Director: Steve Wiel)
D. Project Objectives and Organization (Wiel)

## II. Project Updates and Technical Tasks: Review and Discussions (9:20-10:45)

*Questions to the PAC: Are we on the right track? Is there something else about which we should know to make the project a success?*

A. Task 2.4: Development of cool colored coatings (Akbari et al.) (9:20-9:55)
    **1.** Identify and Characterize Pigments with High Solar Reflectance
    **2.** Develop Software for Optimal Design of Cool Coatings
    **3.** Cool Colored Material Database (new) (*Question for PAC: Shall we proceed in this format?*)
B. Task 2.5: Development of prototype cool-colored roofing materials (Akbari et al.) (9:55-10:15)
    **1.** Review of Roofing Materials Manufacturing Methods
    **2.** Design Innovative Methods for Application of Cool Coatings to Roofing Materials
C. Task 2.6: Field-testing and product useful life testing (Miller/Desjarlais) (10:15-10:45)
    **1.** Building Energy-Use Measurements at California Demonstration Sites
    **2.** Materials Testing at Weathering Farms in California
    **3.** Steep-slope Assembly Testing at ORNL

## III. Summary Comments from PAC members (10:45-11:25)

*Questions to the PAC: How can we successfully market cool roofing products? Is what we have done so far useful? Is what we are planning to do useful? Is there something else we can do to improve our performance?*

## IV. Schedules of PAC meetings and concluding remarks (11:25-11:30)

## V. Adjourn (11:30)

*Attachment 3.*

# CEC-Sponsored
# Cool Roof Colored Materials Project
# Project Team Members


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*Attachment 4.*

# CEC Sponsored Cool Roof Project
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*Attachment 5.*

# Cool Roof Colored Materials
# Project Advisory Committee Members

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*Attachment 6*

# Power Point Presentation

# DEVELOPMENT OF COOL COLORED ROOFING MATERIALS

Project Advisory Committee (PAC) Meeting

**A Collaborative R&D Between Industry**

**LBNL** and **ORNL**

Sponsored by the California Energy Commission (Project Manager: Chris Scruton)

September 11, 2003; LBNL, Berkeley, CA

## Project Goals

- Bring cool colored roofing materials to market
- Measure and document laboratory and *in-situ* performances of roofing products
- Accelerate market penetration of cool metal, tile, wood shake, and shingle products
- Measure and document improvements in the durability of roofing expected to arise from lower operating temperatures



## Project Advisory Committee (PAC) Members

1. Asphalt Roofing Manufacturers Association
2. Bay Area Air Quality Management District
3. California Institute for Energy Efficiency
4. Cedar Shake and Shingle Bureau
5. Cool Roof Rating Council
6. Environmental Protection Agency (EPA)
7. EPA San Francisco Office
8. Mike Evans Construction (replacing Habitat for Humanity)
9. National Roofing Contractors Association
10. Roof Tile Institute
11. DuPont Titanium Technologies
12. Cool Metal Roofing Coalition



## Industrial Partners

- **3M**
- **American Roof Tile Coating**
- **BASF**
- **Custom-Bilt Metals**
- **Elk Manufacturing**
- **Ferro**
- **GAF**
- **Hanson Roof Tile**
- **ISP Minerals**
- **MCA**
- **Monier Lifetile**
- **Shepherd Color Company**
- **Certainteed**



## Project Team

- LBNL
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  - Paul Berdahl PHBerdahl@LBL.gov
  - Ronnen Levinson RMLevinson@LBL.gov
- ORNL
  - Andre Desjarlais (Technical Lead) yt7@ORNL.gov
  - Bill Miller wml@ornl.gov



## Technical Tasks

- 2.4 Development of cool colored coatings
- 2.5 Development of prototype cool-colored roofing materials
- 2.6 Field-testing and product useful life testing
- 2.7 Technology transfer and market plan

## 2.4 Development of Cool Colored Coatings

- Objectives
  - Maximize solar reflectance of a color-matched pigmented coating
  - Compare performance of a coated roofing product (e.g., a shingle) to that of a simple smooth coating
- Subtasks
  - Identify and characterize pigments with high solar reflectance
  - Develop software for optimal design of cool coatings
  - Develop database of cool-colored pigments

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## 2.4.1 Identify & Characterize Pigments w/High Solar Reflectance

- Objective: Identify and characterize pigments with high solar reflectance that can be used to develop cool-colored roofing materials
- Deliverables:
  - Pigment Characterization Data Report (a draft paper is completed)
- Schedule: 6/1/02 – 12/1/04
- Funds Expended 50 %

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## Pigment Characterization Activities

- Paint preparation
- Paint film deposition
- Film property measurement
- Adaptation of Kubelka-Munk (K-M) theory
- Software development
- Pigment classification

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## Recent Film Preparation and Measurements

- Prepared 26 paints from cool-pigment dispersions provided by Ferro, Shepherd
- Created 1:4 and 1:9 tints of 58 paints
- Measured 26 masstones and 116 tints
- Cumulative total: 83 masstones, 116 tints


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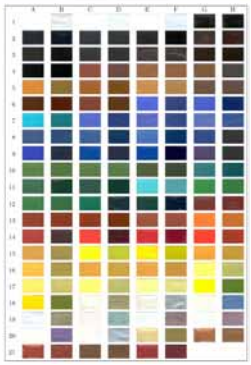
## Paints Over White & Black



- 83 masstones over black, white
- Color distribution:
  - 3 white
  - 19 black/brown
  - 14 blue/purple
  - 11 green
  - 9 red/orange
  - 13 yellow
  - 14 pearlescent

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## Adaptation of Kubelka-Munk Theory

- Kubelka-Munk (K-M) theory relates *paint film* properties to *pigment* properties

| PAINT FILM PROPERTIES | | PIGMENT PROPERTIES |
|---|---|---|
| • reflectance<br>• transmittance<br>• thickness | ⟷ | • scattering coefficient<br>• absorption coefficient |

- K-M theory adapted by LBNL to better characterize pigments that weakly scatter light, especially in near-infrared spectrum
- **LBNL model has been completed**

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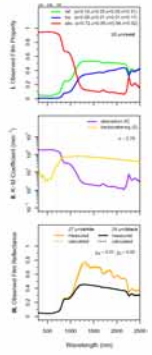
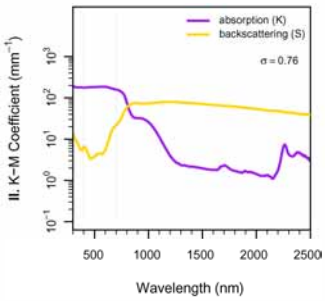
## Sample Pigment Characterization: Chromium Iron Oxide IR Black

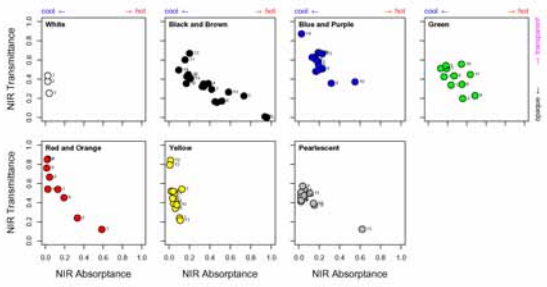


- **Chromium Green-Black Hematite Modified**
- **7% pigment volume concentation**






## NIR Properties of Thin Paint Films






## Next Steps

- Develop theory of mixtures
  - analyze tint measurements
  - prepare and measure nonwhite mixtures
- Share detailed pigment characterizations with industrial partners
- Establish measurement protocols
- Characterization task feeds into the coating design task



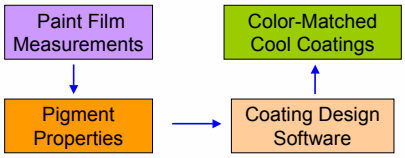
## 2.4.2 Develop a Computer Program For Optimal Design of Cool Coating

- Objective: Develop software for optimal design of cool coatings used in colored roofing materials
- Deliverables:
  - Computer Program
- Schedule: 11/1/03 – 12/1/04
- Funds Expended 8 %



## Coating Design Software

- Estimate coating reflectance from pigment properties (absorption, scattering), film geometry (mixing, layering)
- Recommend pigments & geometry to match color, maximize solar reflectance






## 2.4.3 Cool Colored Material Database (Preliminary)

- Describes 83 single-pigment paints
- Fields include
  - spectral solar transmittance and reflectances (300 - 2500 nm @ 5 nm)
  - pigment chemistry, pigment name, film thickness
  - computed absorption and backscattering coefficients
  - many ancillary values
- Format
  - one tab-delimited text file per paint (easy to read/write)
  - files packed in ZIP archive

## Excerpt From Paint Data File

| lambda (nm) | R.tilde.fv | T.tilde.fv | R.tilde.fw | R.tilde.fb | R.tilde.ow | K (1/mm) | S (1/mm) |
|---|---|---|---|---|---|---|---|
| 330 | 0.0534 | 2.43E-01 | 0.0484 | 0.0468 | 0.0636 | 5.58E+01 | 1.31 |
| 335 | 0.0566 | 2.71E-01 | 0.0494 | 0.0474 | 0.0628 | 5.05E+01 | 1.9 |
| 340 | 0.0596 | 2.95E-01 | 0.0503 | 0.048 | 0.0625 | 4.65E+01 | 2.48 |
| 345 | 0.0623 | 3.18E-01 | 0.0511 | 0.0485 | 0.0632 | 4.30E+01 | 2.92 |
| 350 | 0.0648 | 3.41E-01 | 0.0522 | 0.0486 | 0.0653 | 3.97E+01 | 3.26 |
| 355 | 0.0676 | 3.64E-01 | 0.054 | 0.0485 | 0.0691 | 3.68E+01 | 3.68 |
| 360 | 0.0706 | 3.85E-01 | 0.056 | 0.0487 | 0.0744 | 3.41E+01 | 4.12 |
| 365 | 0.0736 | 4.06E-01 | 0.0587 | 0.0489 | 0.0817 | 3.16E+01 | 4.56 |
| 370 | 0.0761 | 4.25E-01 | 0.0622 | 0.0491 | 0.0912 | 2.96E+01 | 4.84 |
| 375 | 0.0783 | 4.41E-01 | 0.0673 | 0.0491 | 0.105 | 2.78E+01 | 5.08 |
| 380 | 0.08 | 4.58E-01 | 0.0748 | 0.0489 | 0.125 | 2.61E+01 | 4.97 |
| 385 | 0.0818 | 4.73E-01 | 0.086 | 0.0488 | 0.157 | 2.44E+01 | 4.72 |
| 390 | 0.0837 | 4.88E-01 | 0.104 | 0.0489 | 0.212 | 2.30E+01 | 4.6 |



## 2.5 Development of Prototype Cool-Colored Roofing Materials

- Objective: Work with manufacturers to design innovative methods for application of cool coatings on roofing materials
- Subtasks:
  - Review of roofing materials manufacturing methods
  - Design innovative engineering methods for application of cool coatings to roofing materials
  - Accelerated weathering testing



## 2.5.1 Review of Roofing Materials Manufacturing Methods

- Objective: Compile information on roofing materials manufacturing methods
- Deliverables:
  - Methods of Fabrication and Coloring Report (prepared on July 1, 2003)
- Schedule: 6/1/02 – 6/1/03
- Funds Expended 95 %



## Focus: Application of Cool Colors to Roofing Products

- Metal roofing
- Clay roof tiles
- Concrete roof tiles
- Wood shakes
- Asphalt shingles (granules)

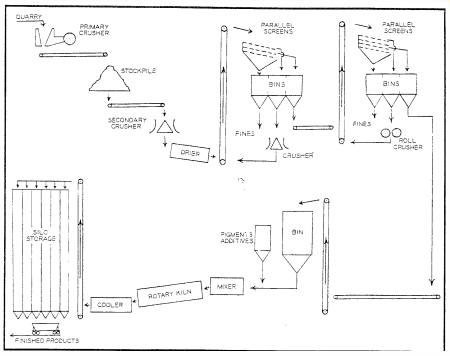


## Manufacturing Shingles: ISP Mineral Products in Ione, CA

- On March 12, we visited the ISP Mineral Products roofing granule plant in Ione, CA



## Schematic of a Granule Production Plant



## Production of Cool Shingles

- Cool granules = cool shingles
- Two principal methods
  - manufacturing granules from highly reflective (e.g., white) rocks (limited by local availability of suitable inert rocks )
  - coating the granules with reflective pigments
- Two-layered approach
  - the granule is pre-coated with a relatively inexpensive NIR-reflective pigment
  - the cool color pigment is applied to the pre-coated granules
- The industry has designed its quality-control laboratories to test the visible color of products; additional instruments is needed to test the solar reflectance and NIR optical properties of products

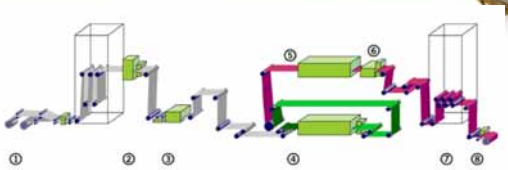


## Manufacturing Metal Roofs:
Steelscape, Inc., Rancho Cucamonga, CA

- On April 30, we visited the Steelscape metal coil coating plant in Rancho Cucamonga, CA
- Four manufacturing lines
  - pickle line
  - cold mill line
  - metal coating line
  - paint line



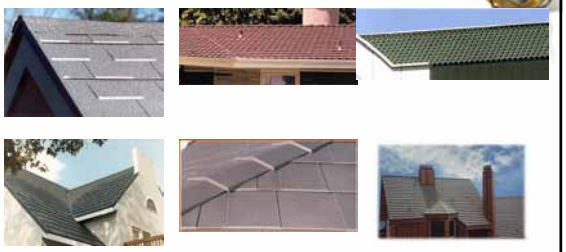

## Schematic of a Metal Coil Coating Plant




1. Entry reels
2. Cleaning unit
3. Chemical coater, applies an initial coating on the steel
4. Finish coater, coats the steel with the finish paint
5. Water quench, painted steel is cooled down to room temperature
6. Excess water remover
7. Exit accumulator
8. Exit reel



## Metal Forming





## Production of Cool Metal Roofs

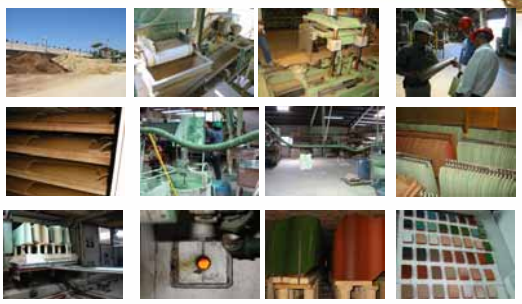
- Of all the colored roofing materials, metal roofs are most suitable for the application of cool colored coatings
- The substrate (bare metal) has high initial reflectance, and is typically coated with two layers (primer + finish)
- If the substrate does not have high initial reflectance, use of a high-reflectance primer could reduce the cool-pigment loading required in the finish



## Manufacturing Clay Roof Tiles:
Maruhachi Ceramics of America, Inc., Corona, CA

- On April 30, we visited the MCA clay roofing tile plant in Corona, CA

## Manufacturing Clay Roof Tiles





## Production of Cool Clay Roof Tiles

- Three ways to improve solar reflectance of colored tiles
  - use raw clay with a low concentration of light-absorbing iron and iron oxides.
  - use cool color pigments in the glaze to provide choice of high-reflectance color
  - use cool pigments over a highly reflective undercoat



## Next Steps

- Visit a concrete tile manufacturing plant
- Update the manufacturing report
- Help needed to arrange plant visits



## 2.5.2 Design Innovative Engineering Methods for Application of Cool Coatings To Roofing Materials

- Objective: Work with manufacturers to design innovative methods for application of cool coatings on roofing materials
- Deliverables:
  - Summary Coating Report
  - Prototype Performance Report
- Schedule: 6/1/02 – 12/1/04
- Funds Expended 7 %



## Engineering Methods: NIR-Reflective Undercoating

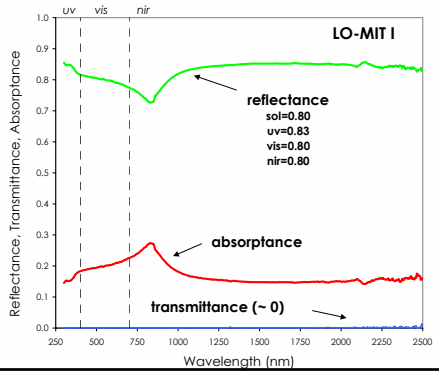
- All cool pigments must have low NIR absorption
- NIR-reflective undercoats (e.g., white, aluminum) improve performance of cool pigments, especially those with high NIR transparency



## Achieving NIR Reflectance > 0.8

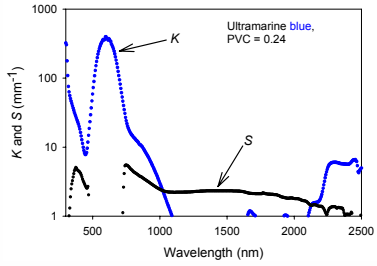
- Best NIR reflectance in a 1 mil (25 μm) film with ~10% $TiO_2$ is about 0.6
- Roughly 3 mils (75 μm) required for NIR reflectance > 0.8
- A thin layer of $TiO_2$-coated mica flakes, $(Fe,Cr)_2O_3$, certain titanates are nearly as good as a thick layer of $TiO_2$
- Pigments with better NIR scattering power?
- Very thin (e.g., 10 nm) continuous metal films/foils/flakes can have NIR reflectance > 0.8 (corrosion an issue, though)

## Flake Al Film with NIR Reflectance = 0.8





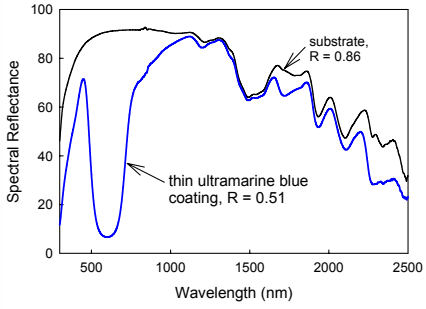

## Absorption *K* and Scattering *S* For Ultramarine Blue




- Strong visible absorption
- Weak IR absorption

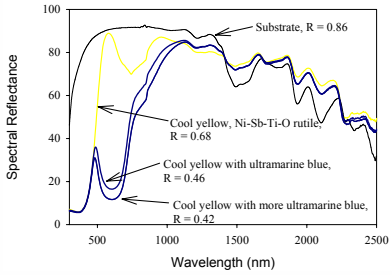


## Ultramarine blue over white






## Bluish Gray Color: Ni-Sb-Ti-O Plus Ultramarine Blue




Other mixtures of ultramarine blue with yellow and orange pigments can produce dark green and brown shades



## Next Steps

- Collaboration with industrial partners
  - pigments: identify/develop suitable undercoats with high NIR reflectance
  - review IR-reflective window technology for ideas
  - propose further recipes for high NIR-reflectance colors
  - investigate methods for factory measurement of shingle NIR reflectance



## 2.6 Field-testing and Product Useful Life Testing

- Objective: Demonstrate, measure and document the building energy savings, improved durability and sustainability of Cool Roof Color Materials
- Subtasks:
  - Building energy-use measurements at California demonstration sites
  - Materials testing at weathering sites in California
  - Steep-slope assembly testing at ORNL
  - Product useful life testing

## 2.6.1 Building Energy-Use Measurements at California Demonstration Sites

- Objective: Setup residential demonstration sites, measure and document the energy savings of Cool Roof Color Materials

- Deliverables:
  - √ Site Selection : Cavalli Hills, Sacramento, CA
  - √ Site Test Plan
  - – Test Site Report
- Schedule: 10/1/02 – 10/1/05
- Funds Expended 26 %

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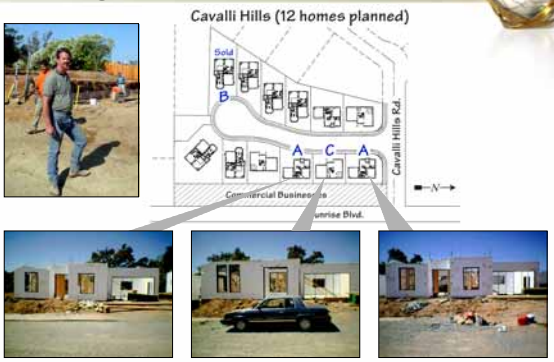
## Mike Evans Construction is building Cavalli Hills




## Cavalli Hills Subdivision Sacramento, CA

- Sacramento Municipal Utility District (**SMUD**) and ORNL will monitoring homes
  - Signed **Memorandum of Understanding**
  - Cool Roof Color Materials (CRCM)
  - Insulated Concrete Form (ICF) walls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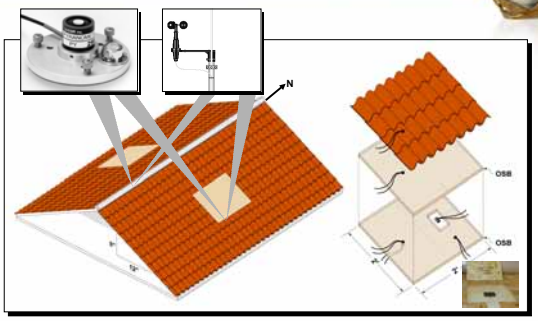
## Roof Instrumentation




OSB Sandwich test panels received by Evans Construction

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## Architectural Plans for Cavalli Hills

Plan A



Plan B

Plan C

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## Implementation Stage for 2.6.1 OUR Next Steps

- **Hanson Roof Tile of *Roof Tile Institute***
  Supplying "Hacienda" Concrete Tile

- **FERRO Corporation**
  Blending cool roof color materials into Hanson's concrete mix
- **Custom-Bilt Metals**
  **Classic Products** } ***Cool Metal Roofing Coalition***
  Supplying *Country Manor Shake*

- **ORNL Contracts Evans Construction**
  ORNL and SMUD commission
  Data Acquisition Systems October 2003

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## 2.6.2 Materials Testing at Weathering Sites in California

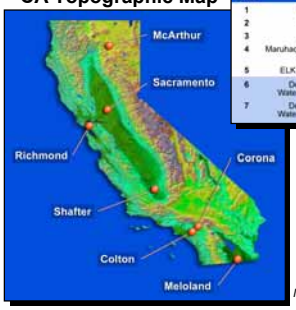
- Objective: Document the change in reflectance and emittance for roof products having Cool Roof Color Materials

- Deliverables:
  - Weathering Studies Report
- Schedule: 10/1/02 – 10/1/05
- Funds Expended 27 %



## Exposure Racks were installed August 03

CA Topographic Map




| Sites | Company | City | County | Climate Zone |
|---|---|---|---|---|
| 1 | Custom-Bilt | Sacramento | Sacramento | 12 |
| 2 | Steelscape | Richmond | Contra Costa | 3 |
| 3 | BASF | Colton | San Bernadino | 10 |
| 4 | Maruhachi Ceramics of America | Corona | Riverside | 10 |
| 5 | ELK Corporation | Shafter | Kern | 13 |
| 6 | Department of Water Resources | McArthur | Shasta | 16 |
| 7 | Department of Water Resources | Meloland | Imperial | 15 |

**Field Exposure Sites**

*Shuttle Radar Topography Mission (SRTM)*
*Space Shuttle Endeavor*
*National Imagery and Mapping Agency (NIMA)*



## Sites at McArthur Farms, Elk Corp, Custom-Bilt Metals and Steelscape


McArthur


Sacramento



Richmond


Shafter



## Sites at MCA, BASF and Meloland


Corona


Colton


Meloland



## CIMIS and EPA's Aeormetric Information Retrieval System data


## Implementation Stage for 2.6.2 OUR Next Steps

- **Monier Lifetile making concrete tile samples**
  Shepherd Color Co. blending "cool" colors into Monier's concrete mix
- **Space available for additional roof samples**
- **Reflectance and emittance measurements collected biannually**

## 2.6.3 Steep-slope Assembly Testing at ORNL

- Objective: Field test Cool Roof Color Materials on the Envelope Systems Research Apparatus (ESRA) to document the effect of reflectance and emittance weathering on thermal performance

- Deliverables:
  - Whole-Building Energy Model Validation
  - Presentation at the Pacific Coast Builders Conference
  - Steep Slope Assembly Test Report
- Schedule: 10/1/02 – 10/1/05
- Funds Expended 10 %

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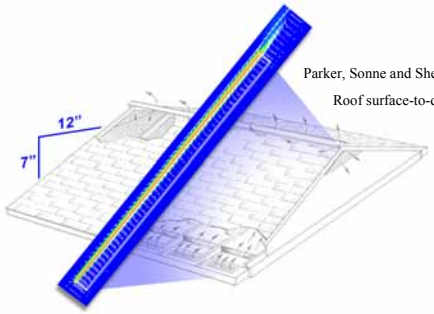
## Natural convection effects prevalent in counter-batten roof systems




Parker, Sonne and Sherwin (ACEEE 2002)

Roof surface-to-deck ΔT's ≈ 14°F (8°C)

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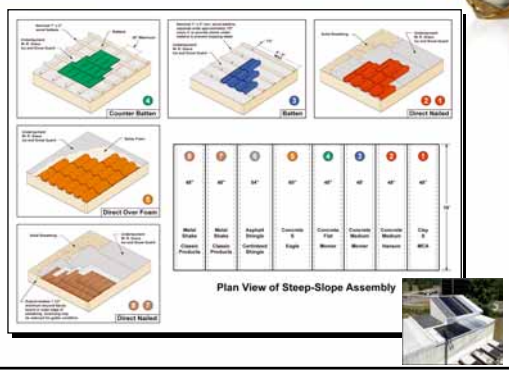
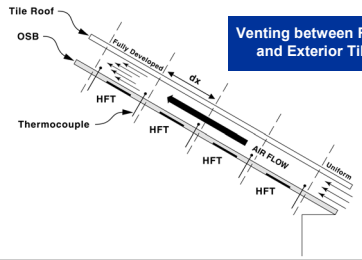
## Roof Tile Institute to install five different tile assemblies on ESRA




## Airflow patterns between roof deck and concrete tile

$$\frac{dT_B}{dx} = \frac{h_R\left(T_{Roof} - T_B\right)}{\dot{m}C_P} + \frac{h_D\left(T_{Deck} - T_B\right)}{\dot{m}C_P} - \frac{kA}{\dot{m}C_P}\left\{\frac{d^2T_B}{dx^2}\right\}$$




**Venting between Roof Deck and Exterior Tile Roof**

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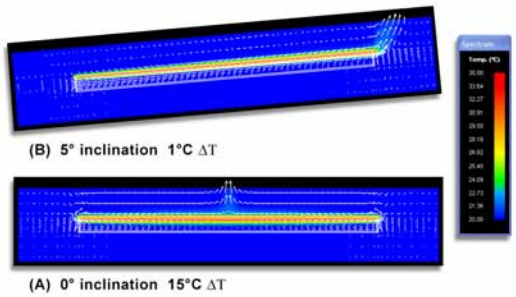
## Naturally induced flow observed at low roof slopes and low ΔTs

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## Implementation Stage for 2.6.3: Next Steps

- **Tennessee Roofing**
  - Remove existing steep-slope metal roofs from ESRA
  - Remove existing thermoplastic membranes
- **Roof Tile Institute installs concrete tile systems**
  1. MCA "S-Mission" Clay tile (Terra Cotta Glaze "cool" color)
  2. Hanson "Regal" Concrete Medium "cool" color same as at Cavalli Hills
  3. Monier Lifetile "Villa 2000" Concrete Medium (Slurry Terra Cotta color)
  4. Monier Lifetile "Sentry Slate" Concrete Flat (Brown)
  5. Eagle "Capistrano" Low Profile Concrete (Slurry Terra Cotta color)
- **Custom-Bilt Metals/Classic Products of Cool Metal Roofing Coalition**
  7. Painted metal shake "cool" color same as at Cavalli Hills
  8. Painted metal shake "standard" color same as at Cavalli Hills

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## March 2004 Meeting

- March 4, 2004
- At CEC, Sacramento

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## Cool Colors Project Website

- Project information (including copies of this presentation) available online at

http://CoolColors.LBL.gov

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