ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

March 11, 2005

To: Chris Scruton
Project Manager
California Energy Commission

From: Hashem Akbari

Subject: Cool Roof Colored Materials—Minutes of March 3, 2005 PAC Meeting

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

On March 3, 2005 from 9:00 am to 12:30 pm, the LBNL/ORNL project staff held at Custom-Bilt facilities (Chino, CA) their sixth (and last scheduled) Project Advisory Committee (PAC) meeting for the CEC-sponsored project on Development of Cool Colored Roofing Materials. Present at the meeting were the LBNL/ORNL project team, members of the PAC, and representatives from 13 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 by the industry partners and the LBNL/ORNL project team.

I. Introduction

A. The PIER Program Team Leader, Ms. Nancy Jenkins (CEC), opened the meeting with some comments on the objectives of the project and the reasons to have PAC meetings (Slides 1-2). She also thanked Custom-Bilt Metal for hosting the PAC meeting. The meeting participants (PAC members, project team members, and industrial partners) introduced themselves and stated their specific interests in the project (Slides 3-4).

B. Akbari introduced the research team at LBNL and ORNL (Slide 5-6). He outlined the technical tasks to be discussed at the meeting. He mentioned that since last PAC meeting we have completed several major tasks.

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).

1. *Subtask 2.4.1: Identify and Characterize Pigments with High Solar Reflectance* (Slides 8–9). Akbari reported that the Characterization Task is completed and that we have summarized the results in two papers (Levinson, R., P. Berdahl and H. Akbari. 2005. Solar spectral optical properties of pigments, Part I: model for deriving scattering and absorption coefficients from transmittance and reflectance measurements; Levinson, R., P. Berdahl and H. Akbari. 2005. Solar spectral optical properties of pigments, Part II: survey of common colorants) submitted to *Solar Energy Materials & Solar Cells*. Both papers are in press.

   Akbari introduced Levinson to discuss tasks 2.4.2 and 2.4.3.

   Action Items:

   - None.

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2. *Subtask 2.4.2: Develop a Computer Program for Optimal Design of Cool Coatings* (Slides 10-12). Levinson reported that this task is about 90% completed. Upon the approval of CEC Project Manager (Chris Scruton) the completion date has been revised to May 1, 2005. The coating formulation software has three components: pigment-mixture reflectance model, optimization algorithm, and pigment characterization database. We have completed the pigment database and we are improving mixture reflectance and optimization and models. We expect the alpha version of the software to be released to partners in March 2005.

   Action Items:

   - None.

3. *Subtask 2.4.3: Cool-colored Material Database* (Slides 13-16). Levinson reported that this task is also completed and delivered to CEC in December 2004. (The task was originally scheduled for delivery on June 1, 2005.) The database can be found online at http://CoolColors.LBL.gov/LBNL-Pigment-Database/database.html .
   The images and charts of the database are available to public. The spectral datafiles are encrypted and at this time are only available to industry partners.

   The database has information on 87 commonly used pigments in masstones, tints, and nonwhite mixtures. The pigment database includes name, chemistry, particle size, concentration, solar spectral properties, photographs, and commentary by LBNL scientists. The database can be used to identify hot and cool pigments and formulate cool nonwhite coatings. Levinson gave a brief demonstration of the database.

   Action Items:

   - None.

Overall discussion of Task 2.4. There were several clarifying questions on each of the subtasks. The participants encouraged the expansion of the database to include other information such as cost, environmental effects, applications, etc. Most participants considered the database a very useful tool for the development of cool colored roofing materials. It was mentioned that the database needed to be maintained and new materials added as they become available.

B. Task 2.5: Development of Prototype Cool-Colored Roofing Materials (Slide 17). 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 18-19). Akbari mentioned that the work on this subtask is completed. A report summarizing the results of literature review and visits to several roof materials manufacturing plants (asphalt shingles, metal roofing, roofing granules, clay roof tiles, and concrete tile) has been prepared and is available on our Cool Colors web site (http://coolcolors.lbl.gov). Akbari mentioned that the report has been reviewed by our industry partners and their comments have been incorporated in the report. The report has been submitted for LBNL publication. The report has also been published in *Western Roofing* magazine in two parts (Jan/Feb and Mar/Apr 2005). [These articles are available at
http://www.westernroofing.net/asphlat_osb_articles/akbari_materials1.pdf
http://www.westernroofing.net/asphlat_osb_articles/akbari_materials2.pdf .]

Action Items:

- None.

2. *Subtask 2.5.2: Design Innovative Methods for Application of Cool Coatings to Roofing Materials* (Slides 20-21). Akbari started the presentation for this task by mentioning that this task has been one of the primary focuses of the project during the last year. During this period, we have worked closely and iteratively with 12 companies (shingle/granule, tile/tile

coatings, metal/metal coatings, and pigment) to produce prototype cool colored roofing products. The results have been prototypical production of over 200 shingles, 50 tiles or tile coatings, and 20 metal panels. The iterative and dynamic interaction with manufacturers has included selection of pigments, choice of base coats (in a two-layer coating application), and components to avoid.

Akbari then mentioned that the best way to appreciate the significant progress made in these tasks is to hear the industry partners present their own summaries of the material development effort. Seven industry partners (or groups of partners) made presentations: 3M, Elk, ISP Minerals, Ferro, Shepherd Color, SteelScape/BASF/Custom-Bilt, and American Rooftile Coatings. The following are highlights of the presentations of the industry partners (Full presentations are shown in Attachment 7).

3M presentation:
Dr. Chris Gross gave a presentation of the 3M efforts in developing cool colored granules used in roofing shingles. Gross started by giving a brief background of 3M's collaboration with LBNL/ORNL. He mentioned that shingles are the dominant roofing materials used in residential markets. Since granules cover over 97% of the area of roofing shingles, developing reflective colored granules is the key in developing reflective shingles. Gross briefly discussed 3M's effort in characterizing the effect of infrared reflective pigments, pigment coverage of the granules, the grade of granules, multi-coating application, and the post treatment of granules. He then disclosed that 3M has developed cool colored granules with the following solar reflectance: Cool Tan – 32%; Cool Brown – 25%; Cool Blue Grey – 27%; Cool Grey – 27%; WA9300 White – 29% (left to right in Figure below, with White omitted).

Gross mentioned that granules with higher solar reflectance can be developed but the cost would be higher. He concluded his comments by outlining the future research needs as: optimize coating technology; accelerate agency (CRRC, Energy Star) qualifications; develop relationship between granule reflectance values and ultimate shingle reflectance; and collaborate to quantify savings potentials of reflective granule/shingle products.

Elk Corporation presentation:
Dr. Lou Hahn presentation started with identifying three key parameters for development of cool colored shingles: performance, aesthetics, and cost. Elk's goal is to achieve these performance criteria at proper balance. He discussed in details the Elk's effort in meeting the performance criteria for cool shingles, then added that Elk has developed 4 cool colored

shingles (in two designs) with reflectivity greater than 0.25. Samples of these shingles are being tested at demonstration site in Redding CA and at ORNL facilities. The following pictures show two examples of cool colored shingles.

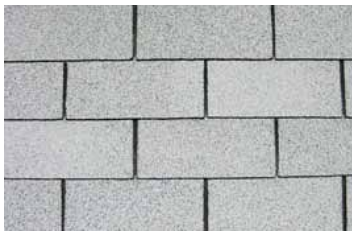
Hahn concluded his comments by reiterating Elk's commitment for development of cool colored shingles and identifying a few task for continuing research: (1) continue working with the labs to produce colored cool shingles at attractive cost; (2) finalize the use of the Devices and Services Solar Spectrum Reflectometer (ASTM C1549) for all shingle reflectance testing; (3) develop software to estimate the cooling energy savings and peak demand reduction achieved by installing cool shingles on specific buildings; and (4) install and monitor the solar reflectance and color change of the shingles installed at the California demonstration sites and at ORNL test facilities.

ISP Minerals presentation:
Dr. Ingo Joedicke mentioned that the ISP collaboration with LBNL started in 1994 with the characterization of the spectral solar reflectance of existing granules and the development of ultra-white cool granules. The results have been the A-707 ultra-bright white granules with a solar reflectance greater than 0.5. Under the current CEC-sponsored project many prototype granules have been developed and tested. The following pictures show examples of three cool colored granules with solar reflectances (R) of 0.28, 0.36 and 0.37.

He added that the technologies for development of cool granules are: (1) eliminate "hot" pigments; (2) incorporate IR-reflective pigments; (3) maximize coating coverage through use of high pigment loadings and multiple coatings; and (4) use of reflective undercoats in a two-layered coating application. Joedicke concluded his comments by reviewing the collaborative tasks completed to date and specifying task for the next steps: (1) continue collaborative efforts with the labs to increase reflectivity and reduce costs; (2) work with project team to identify new materials and techniques; (3) establish test roofs; (4) expand to large-scale demonstrations; (5) review pigment database – need to expand; (6) evaluate coating formulation software; (7) determine weathering benefits of cool roofing; and (8) develop tools to accurately measure solar reflectance of manufactured shingle.

Standard Shingles

R=0.23



R=0.27

R=0.28

Cool Shingles

R=0.28

R=0.36

R=0.37

Ferro presentation:
Mr. Ken Loye started his presentation by reviewing the public interest in "Cool Roofs" since March 2003. He showed slides of a Google search with key words "cool" and "roof" in March 2003 yielding 700,000 entries, expanding to 1M in October 2004, and to 2.4M in February 2005. He then reviewed the application of cool-colored pigments in several industries including metal roofs and sidewalls (coil coatings); EPDM, single-ply, and tile roofing; asphalt shingles (largest roofing market sector); decking (wood, concrete and plastic composite); concrete (roof tile, swimming pool deck, flat tile); vinyl siding for homes; window frames (profiles); automotive parts; and cedar shakes. He then presented some data on the excellent durability and fade resistance of cool colored coatings. He concluded his comments by suggesting a few tasks for the continuation of the project: (1) large-scale demonstrations showing $ and KWh savings; (2) software to estimate the cooling energy savings; (3) value of technology to lessen peak energy demand; (4) monitor color and reflectivity change over time; (5) work with labs on reflectivity improvement; (6) monitor thermal performance over time; and (7) develop predictive software for cool coating design.

Shepherd Color presentation:
Mr. Tom Steger introduced the organization of Shepherd Color Company and the market that they serve (i.e., roofing granules; metal building products; vinyl siding, windows, doors automotive; wood coatings; and military). He mentioned that cool roofing coatings should be heat stable, weather resistant, and chemical resistant. He then showed two slides of the coatings being tested at the California weathering sites. The outreach activities of Shepherd Color include working with professional associations (e.g., NCCA and CMRC) and participating in trade shows (NRCA, WSRCA, Metalcon, ICE, CSI, NPE, ANTEC, VSI). He then presented samples of publications developed for market education. He then stated the

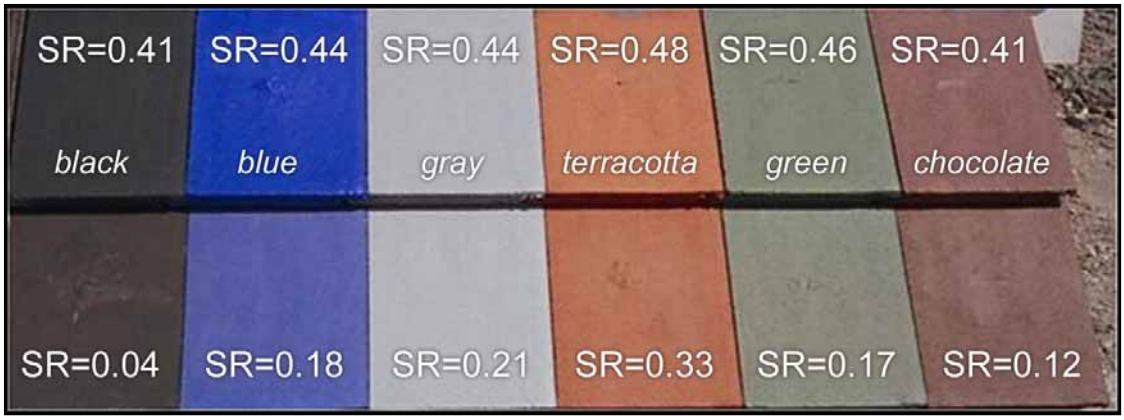
challenge of producing reflective dark materials. He concluded his comments by outlining research ideas such as: (1) cooperate with LBNL, ORNL, and industry to improve reflectance of roofing materials; (2) to develop cool materials that are durable and darker in color; (3) to overcome inertia of downstream customers; and (4) continue to exhibit and promote "Arctic" cool technologies (the Shepherd trademark).

BASF, Steelscape, Custom-Bilt Metals presentation:
Ms. Michelle Vondran of Steelscape made a presentation on behalf of all three companies by providing a short history of the project evolution. During this period BASF shared non-proprietary research results on cool formulations; prepared films for optical measurements and provided wet samples of ULTRA-Cool paints (over 100 samples); supplied coating mixing and application equipment to the project; provided accelerated weathering test results; and assisted with evaluation of the coating formulation software. Custom Bilt provided manufacturing process information; shared market data and sales strategies; and supplied roofs for test homes in Sacramento as well as roof sections for testing at ORNL. Steelscape provided metal samples (both bare and painted) as needed, and supplied detailed information on the coil coating process. Vondran then reviewed some results for product testing of painted metals. A case study was conducted in Georgia for two new schools of identical footprint (90,000 square feet). The one school in Baggett County had a conventional green color standing seam metal roof with solar reflectance of 12%, the other school in Poole County has the same color metal roof but with solar reflectance of 29%. Greystone Power Utility measured an energy savings of about $8800 for the first year of operation, which Scichili attributed the savings to the cool colored metal roof. Vondran also showed data from Sacramento demonstration buildings depicting a reduced heat flux through the roof. She concluded her remarks by outlining a few tasks for continuation of the research: (1) developing software to estimate the cooling energy savings and peak demand reduction achieved by installing cool roofs on specific buildings; (2) continue monitoring the solar reflectance and color change of the materials installed at the California weathering sites; (3) continue monitoring the solar reflectance, color change, and thermal performance of materials at ORNL test facilities and the Sacramento test homes; (4) expanding cool coating database; (5) developing predictive software for design of cool coatings; (6) carrying out a large-scale demonstration; and (7) educating architects, specification writers and consumers.

American Rooftile Coating presentation:
Mr. Joe Reilly started his presentation by reviewing the history of ARC and its collaboration with the "Cool Colors" project. He then showed samples of the cool coatings developed by ARC (see picture below). The chocolate coating is being tested at the Sacramento demonstration houses and at the California weather farms. The measured data show a decrease of over 50% in heat flux through the roof by application of cool coatings. The research topic highlighted by Reilly included: (1) improving the reflectance of our coatings by including new pigments; (2) developing instruments to measure the solar reflectance of colored concrete tiles in the field on curved surfaces; (3) developing tools to estimate the cooling energy savings and peak demand reduction achieved by installing cool coatings on specific buildings; (4) monitoring the solar reflectance and color change on roof materials installed at the California weathering sites; (5) testing the solar reflectance, color change, and thermal performance of roofing materials at ORNL test facilities; and (6) market deployment and large-scale demonstration; this could be driven by rebate or tax credit incentives.

Action Items:

- None.



3. *Subtask 2.5.3: Accelerated Weathering Testing* (Slides 22-25). Berdahl led the brief discussion of this task by reviewing the Task's objective. He indicated that two review papers are under preparation: Accelerated testing of roofing material (Task 2.5.3) and Weathering of roofing materials (Task 2.6.4). He distributed a bibliography for both papers. The accelerated testing of roofing materials would be useful provided the weathering is understood. The processes typically used for accelerated testing include UV, moisture, and cyclic heating. The literature includes information on the accelerated aging of polymer coatings on various substrates, inorganic and organic pigments, asphalt based materials, tiles, and wood and shakes. Several case studies by our industry partners (Ferro, BASF) also exist.

   For the review paper of weathering of roofing materials, the environmental stresses include UV, heat, moisture, wind, hail, freeze-thaw, SO_2, NO_2, and biological growth. Photo-oxidation of polymers, asphalt, and organic pigments is also an issue. For some materials corrosion, change in chemistry, and efflorescence are important factors. Finally, mechanical stresses (wind, differential thermal expansion) need to be addressed. Berdahl asked partners for any other available information that can help with preparation of these two review papers.

   Action Items:

   - Industry partners to share and provide additional accelerated weathering data.

Overall discussion of Task 2.5. During the presentation of Task 2.5 there were several clarifying question from the project team and the industry partners. A question regarding the incremental cost of cool colored roofs by Mr. Gregg Ander (SCE) prompted good discussion. Ms. Nancy Jenkins stated that cost is a decisive factor in promoting coot roofs for Title 24, developing incentive programs, and carrying out a cost/benefit analysis for the homeowners. Jenkins also asked the industry partners whether it would be more efficient to provide "rebates" to homeowners or to manufacturers/developers/specifiers. Jim Dunn (Ferro) replied that the consumers should somehow benefit from the rebate. Ms. Kathy Diehl (EPA) argued that it might be more effective to offer the incentive to developers. Mr. Jerry Vandewater (MonierLifetile) agreed with Diehl.

C. **Task 2.6: Field Testing and Product Useful Life Testing** (Slides 26). Miller started discussion of the progress on this task by briefly reviewing the task objectives. He then presented details of individual tasks.

   1. *Task 2.6.1: Building Energy Use Measurements at California Demonstration Sites* (Slides 27-32). Miller reviewed the status of the four buildings being monitored at the Cavalli Hills demonstration. Miller showed that the heat fluxes through the cool roof metal and concrete tile roofs compared to standard color roofs have decreased by 36% and 19%, respectively. Instrumentation for a pair of demonstration sites at Redding, CA (using composition shingles from Elk) has been installed. In late March, we will install the dataloggers for these houses. These same shingles are also installed at ORNL to test their thermal performance. The cool

shingle at ORNL has an 11K lower surface temperature with heat flux through the roof reduced by 75%. We are planning two have two other demonstration houses for shingles in Martinez, CA. Miller concluded that, upon approval of the CEC project manager, the delivery date for this task will be been changed to October 1, 2006.

Discussion of Tasks 2.6.1. Several clarifying questions from the PAC members were answered.

Action Items:

- None.

2. *Subtask 2.6.2: Materials Testing at Weathering Farms in California* (Slides 33-35). Miller mentioned that all samples have been installed at the seven weathering farms in California and we have collected weathering data for about 1½ year. He showed reflectance data for new and 4-month weathered concrete tile samples provided by American Rooftile Coating with practically no change in solar reflectance over the four-month period

   Action Items:

   - None.

3. *Subtask 2.6.3: Steep-Slope Assembly Testing at ORNL* (Slides 36-41). Miller reviewed the status of the current activities for testing of the roofing materials at the Envelope Systems Research Apparatus (ESRA) at ORNL. He showed pictures of the ESRA facilities with new concrete tiles and roofing shingles. He also showed data on heat flux conducted through the roof for control asphalt shingles, cool asphalt shingles, concrete tile, and clay tile. The concrete tile (standard color) showed a comparable performance to cool asphalt shingles.

   Miller also showed validation data comparing the results of AtticSim with measured data for an asphalt shingle roof being tested at ORNL.

   Action Items:

   - None.

4. *Subtask 2.6.4: Product Useful Life Testing* (Slides 42-44). Miller/Berdahl led the discussion of this task by briefly reviewing the task's objectives. Miller showed accelerated aging results for the fade resistance and gloss retention of painted metals. He mentioned that the data indicates that the performance of cool colored coatings have been consistently better that the standard coatings.

   Action Items:

   - Berdahl and Miller to consult with Elk, Certainteed, and GAF to finalize the experimental plan.

Overall discussion of Task 2.6. During the presentation of Task 2.6 there were several clarifying question from the project team and the industry partners. Anders inquired about the presence of radiant barriers in the demonstration buildings. Ed Becker of Southern California Gas asked about the parameters monitored at the demonstration sites. Miller briefly reviewed the monitoring points in the demo buildings. Peter Turnbull (PG&E) asked whether the demo buildings are occupied. Anders asked about the normalization procedure for the occupancy effect. He continued that the measured data are required for developing utility programs for cost-effective measures.

5. *Subtask 2.7.1: Technology Transfer* (Slides 45-47). Akbari mentioned that technology transfer has been an integral part of the project since inception. During the last six months, the project team has completed or published seven articles.

   Action Items:

   - None

III. Summary Comments from PAC Members

At the conclusion of the meeting, each PAC member and participants provided some summary comments. Turnbull mentioned that PG&E is interested in this project for both the energy saving and peak demand reduction potentials of cool roofs. Turnbull also mentioned that he is interested to expand the Title 24 standard (for year 2008) to include cool roofs for sloped residential and small commercial buildings. Many participants agreed that upgrading to Title 24 for cool roofs is important to both industry and utilities. Finally, Turnbull mentioned that down-sizing of the AC system should be part of any future analysis. Ed Becker (SCG/SDG&E) stated his satisfaction with the project and mentioned that SCG/SDG&E are ready to use the information generated in this project to develop utility-sponsored incentive programs. This effort will be combined with other parallel measures. Jenkins mentioned that the data generated in this project will be used in development and refinement of an attic model.

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 has achieved major milestones and is on the right track and expressed satisfaction with the direction and accomplishments of the project to date.

IV. Schedules of PAC Meetings and Concluding Remarks (Slides 48-49).

Ms. Jenkins mentioned that this is our last scheduled PAC meeting under the current contract. She stated that PIER program is very pleased with the industry and national labs collaboration in this project. She added the PIER program is considering options for the continued industry/national labs collaboration on this important project. She once more expressed her thanks to the Custom-Bilt Metal for hosting the PAC meeting. All materials related to the project will be posted to http://CoolColors.LBL.gov .

V. Adjourn.

The PAC meeting adjourned at 12:30. After lunch, a few participants toured the production facilities of the Custom-Bilt Metal.

Attachment 1.

Attendance, Cool Colored Roof PAC Meeting
Custom-Bilt Metal, Chino CA
March 3, 2005

Name	Affiliation	Phone Number
Akbari, Hashem	Lawrence Berkeley National Laboratory	510-486-4287
Ander, Gregg	SCE	626-633-7160
Becker, Ed	SoCalGas/SDG&E	213-244-3680
Berdahl, Paul	Lawrence Berkeley National Laboratory	510-486-5278
Chiovare, Joe	Custom-Bilt Metals	909-664-1550
Chiovare, Tony	Custom-Bilt Metals	909-664-1550
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
Dunn, Jim	Ferro Coro.	323-829-7577
* Greaves, Gerry	Owens Corning	740-321-7780
Gross, Chris	3M Minerals	651-736-4379
Hahn, Lou	Elk Manufacturing	972-872-2293
Jenkins, Nancy	CEC	916-654-4739
Joedicke, Ingo	ISP Minerals	301-714-1481
Levinson, Ronnen	Lawrence Berkeley National Laboratory	510-486-7494
Loye, Ken	Ferro Corp.	216-750-7511
Miller, William	Oak Ridge National Laboratory	865-574-2013
Reilly, Joe	American Rooftile Coatings	714-680-6436
Shiao, Ming	CertainTeed	610-341-6431
Scichili, Robert	BASF/Consultant to Custom-Bilt Metals	972-234-0180
* Scruton, Chris	CEC	916-653-0948
Srinivasan, Krishna	GAF	973-628-3043
Steger, Tom	The Shepherd Color Co.	513-874-0714
Suzuki, Yoshi	MCA Clay Tile	800-736-6221
Sypowics, Bob	American Rooftile Coatings	714-680-6436
Turnbull, Peter	PG&E/CRRC	415-973-2164
Vondran, Michelle	Steelscape	909-484-4623
Vandewater, Jerry	MonierLifetile	805-379-7636

* A few participants joined the PAC meeting by telephone.

Attachment 2.

Agenda

Development of Cool Colored Roofing Materials

Project Advisory Committee Meeting

9:00 am to 12:30 pm (PST)
Thursday, March 3, 2005
Custom-Bilt Metals
13940 Magnolia Ave.
Chino, CA 91710
Conference Calling: 1-800-537-9776; Pin number 2241357

Contact Information: Connie C. ((909) 664-1500, conniec@custombiltmetals.com)

III. Introduction (9:00-9:20)

A. Introduction (CEC Project Manager: Chris Scruton/Nancy Jenkins)
B. Opening remarks and the objectives of the PAC meetings (CEC Project Manager: Chris Scruton/Nancy Jenkins)
C. Introduction of the ORNL and LBNL project staff (Hashem Akbari)
D. Project Objectives and Organization (Akbari)

IV. Project Updates and Technical Tasks: Review and Discussions (9:20-11:50)

Questions to the PAC: How shall we continue? How can we deploy results and products?

A. Task 2.4: Development of cool colored coatings (Akbari/Berdahl/Levinson) (9:20-9:35)
  1. Identify and Characterize Pigments with High Solar Reflectance (1 min)
  2. Develop Software for Optimal Design of Cool Coatings (5 min)
  3. Cool Colored Material Database (9 min)

B. Task 2.5: Development of prototype cool-colored roofing materials (Akbari et al.) (9:35-11:20)
  1. Updates on Review of Roofing Materials Manufacturing Methods (1 min)
  2. Design Innovative Methods for Application of Cool Coatings to Roofing Materials (5 min)
  3. Presentations by industrial partners (90 min)
    - 3M
    - Elk Manufacturing Corp
    - ISP Minerals
    - Ferro
    - Shepherd Color
    - Steelscape/BASF/Custom-Bilt
    - American Rooftile Coating
    - *Others*
  4. Accelerated Weathering Testing (9 min)

C. Task 2.6: Field-testing and product useful life testing (Miller/Desjarlais/Berdahl) (11:20-11:45)
  1. Building Energy-Use Measurements at California Demonstration Sites (8 min)
  2. Materials Testing at Weathering Farms in California (5 min)
  3. Steep-slope Assembly Testing at ORNL (5 min)
  4. Product Useful Life Testing (7 min)

D. Technology transfer and market plan (Akbari) (11:45-11:50)

V. Discussion of Key issues, and Comments from PAC members (11:50-12:20)

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?

VI. This is the last PAC meeting under the current phase of the project; concluding remarks (12:20-12:30)

VII. Adjourn (12:30)

VIII. Working Lunch, discussions (12:30 – 1:30 pm)

IX. Visit to Custom-Bilt Metals facilities (1:30 – 3:00 pm) (Optional)

Attachment 3.

CEC-Sponsored
Cool Roof Colored Materials Project
Project Team Members

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Attachment 4.

CEC Sponsored Cool Roof Project
Industrial Partners
(* indicates new member)

1. Tony Chiovare
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   lhahn@elkcorp.com
3. Ingo Joedicke
   ISP Minerals
   301-714-1481
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Attachment 5.

Cool Roof Colored Materials
Project Advisory Committee Members
Welcome PG&E/CRRC and SCE (New PAC members)

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Attachment 6

Project Team Presentation Materials

Development of Cool Colored Roofing Materials

Project Advisory Committee (PAC) Meeting

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

March 3, 2005; Custom-Bilt Metals, Chino, 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. Cedar Shake and Shingle Bureau
4. Cool Metal Roofing Coalition
5. Cool Roof Rating Council
6. DuPont Titanium Technologies
7. Environmental Protection Agency (EPA)
8. EPA San Francisco Office
9. National Roofing Contractors Association
10. Pacific Gas and Electric Company (PG&E)
11. Tile Roofing Institute
12. Southern California Edison Company (SCE)

Industrial Partners (Welcome new partners)

- 3M
- Akzo Nobel
- American Roof Tile Coating
- BASF
- CertainTeed
- Custom-Bilt Metals
- Elk Corporation
- Ferro
- GAF
- Hanson Roof Tile
- ISP Minerals
- MCA
- Monier Lifetile
- Owens Corning
- Steelscape
- Shepherd Color

Project Team

- **LBNL**
  - Steve Wiel (Project Director) SWiel@LBL.gov
  - Hashem Akbari (Technical Lead) H_Akbari@LBL.gov
  - Paul Berdahl PHBerdahl@LBL.gov
  - Ronnen Levinson RMLevinson@LBL.gov
- **ORNL**
  - André 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 & characterize pigments with high solar reflectance
  - Develop software for optimal design of cool coatings
  - Develop database of cool-colored pigments

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 (**2 journal papers in press**)
- Schedule: 6/1/02 – 12/1/04 → 12/31/04
- Funds Expended 100%

Completed Study of Masstones (Pure Color Paints)

- Two articles (model, pigment survey) in press at *Solar Energy Materials & Solar Cells*
- Journal reviewer comments:
  - "Great work with extensive detail; I have not seen such detail on pigments since work in the 1960s by the arerospace companies. It is nice to see such a seminal work in one location and with one set of testing methodologies. Please publish."
  - "Very nice work, uniform and detailed—the beginnings of a handbook. Very valuable to my industry (paint formulation). If Elsevier puts together a Materials Property Handbook, the results of this work should be in it."

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 → 5/1/05
- Funds Expended 90%

Overview of Coating Formulation Software

- Tool to produce recipes for cool (solar reflective) coatings matching target color
- Components
  - pigment-mixture reflectance model
  - optimization algorithm
  - solar spectral optical properties of many pigments (LBNL Pigment Database)

Status of Coating Formulation Software

- Under development
  - pigment database complete
  - software & model being improved
  - alpha version to be released to partners in March 2005

2.4.3 Develop Database of Cool-Colored Pigments

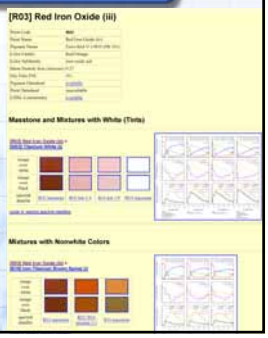
- Objective
  - Develop a database that can be readily used by the industry to obtain characteristic pigment information for the design of cool-colored coatings
- Deliverables
  - Electronic-format Pigment Database
- Schedule: 6/1/03 – 6/1/05 →12/31/04
- Funds Expended 100%

Database Now Online

- User-friendly database online at **http://CoolColors.LBL.gov/LBNL-Pigment-Database/database.html**
  - images and charts available to public
  - spectral datafiles encrypted
  - datafile password available from Ronnen

LBNL Pigment Database: Contents

- Describes 87 pigments
  - masstones (pure colors)
  - tints (mixtures with white)
  - nonwhite mixtures
- Pigment details
  - name, chemistry, particle size, concentration, solar spectral properties, photographs, LBNL commentary
- Browsable web pages
  - images, charts, tables, text
- Machine-readable datafiles
  - matrices of spectral data



LBNL Pigment Database: Applications

- Identifying hot, cool pigments
  - Avoiding hot pigments as important as including cool pigments
  - User-friendly database easy to browse
- Formulating cool nonwhite coatings
  - Database includes tables of solar spectral radiative properties usable in LBNL and proprietary coating formulation tools

2.5 Develop 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 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 100%

Updated and Finalized the Roofing Manufacturing Report

- Technical report in press
  - Akbari H., R. Levinson, and P. Berdahl. 2004. A review of methods for the manufacture of residential roofing materials. Berkeley, CA; Lawrence Berkeley National Laboratory Report LBNL-55574.
- Report to be serialized in *Western Roofing Insulation & Siding* (spring 2005)

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 → 5/1/05
- Funds Expended 95%

Engineering Methods: Partners' Presentations

- 3M
- Elk Corporation
- ISP Minerals
- Ferro
- Shepherd Color
- Steelscape/BASF/Custom-Bilt
- American Rooftile Coatings

2.5.3 Accelerated Weathering

- Objective: Identify latent material defects early by accelerated weathering
- Deliverables:
  - Accelerated Weathering Testing Report
- Schedule: 11/1/02 – 6/1/05 → 10/1/05
- Funds Expended 40%

Two Review Articles in Preparation

- Accelerated testing of roofing materials (Task 2.5.3)
- Weathering of roofing materials (Task 2.6.4)
- Tutorial information
- Providing a bibliography to our industry partners so they can help us fill the gaps

Outline: Accelerated Testing of Roofing Materials

- Useful provided weathering is "understood"
- Equipment used: UV, moisture, cyclic heating
- Summary of literature
  - Polymer coatings on various substrates
  - Inorganic and organic pigments
  - Asphalt-based materials
  - Tiles
  - Wood shakes
- Case studies (Ferro/BASF data and others)

Outline: Weathering of Roofing Materials

- Environmental stresses include UV, heat, moisture, wind, hail, freeze-thaw, SO_2, NO_2, biological growth, …
- Photooxidation of polymers, asphalt, organic pigments
- Some corrosion chemistry (metal, cement, asphalt,...), efflorescence
- Mechanical stresses – wind, differential thermal expansion – need for structural flexibility

2.6 Field-testing and Product Useful Life Analysis

- **Objective:** Demonstrate, measure and document the building energy savings, improved durability and sustainability of Cool Roof Color Materials (CRCMs)
- 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 Measures at California Demonstration Sites

- **Objective:** Setup residential demonstration sites; measure and document the energy savings of CRCMs
- Deliverables:
  - √ Site Selection: Cavalli Hills, Fair Oaks,CA
    Redding, CA
    Martinez, CA
  - √ Site Test Plan
  - – Test Site Report
- Schedule: 10/1/02 – 10/1/05 → 10/1/06
- Funds Expended 85 %

Cavalli Hills Demonstrations Continue to Show Positive Benefits of CRCMs

Week starting	Pair of Homes with and without CRCMs	
	Concrete tile roofs (% drop in $Q_{west\ roof}$)	Painted Metal Roofs (% drop in $Q_{south\ roof}$)
Sep. 3, 04	20.6	35.5
Sep. 10, 04	15.4	35.9
Sep. 17, 04	23.9	38.0
Sep. 24, 04	14.6	34.4
Average	**18.6**	**36.0**

Percentage is based on the reduction in roof heat transfer during the sunlit hours for a roof with CRCM as compared to one without CRCMs.

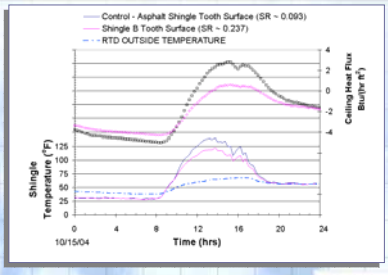
Demonstration Homes Provided by Elk Corp and Ochoa & Shehan Custom Homes

2605 Eel Street, Redding CA

2605 Loggerhead St., Redding CA

East TN Field Data Comparing Shingle (SR 0.26) to Shingle (SR 0.09)

CRCM Shingle Drops Surface Temperature ~11°C (20°F) and Reduced Heat Flux by ~75%



2.6.1 Next Steps

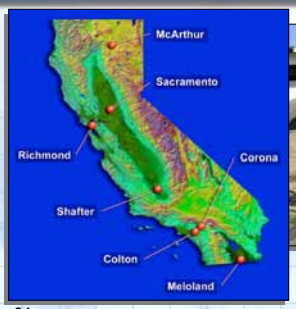
- **Establish Demonstration Sites**
  - One Pair of Composition shingles — **Redding, CA**
    - DAS on line April, 2005
  - Second Pair of Composition shingles — **Martinez, CA**
- **Report on Demonstration Sites 10/01/06**

2.6.2 Materials Testing at Weathering Sites in California

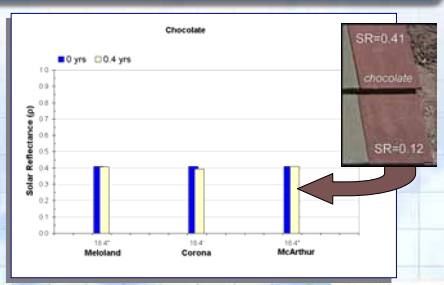
- **Objective:** Document the change in reflectance and emittance for roof products having Cool Roof Color Materials
- Deliverables:
  - Weathering Studies Report
- Schedule: 10/1/02 – 10/1/05 → 10/1/06
- Funds Expended 70 %

Concrete and Clay tile and Painted Metals under exposure

Clay and Painted Metal exposed for 1½ years



Concrete Tile Coatings under exposure at all seven weathering sites



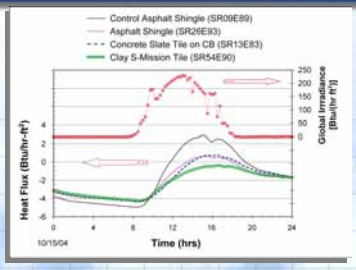
2.6.3 Steep-slope Assembly Testing at ORNL

- **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:
  - Attic Model Validation
  - Steep Slope Assembly Test Report
  - Presentation at the Pacific Coast Builders Conference
- Schedule: 10/1/02 – 10/1/05
- Funds Expended 70 %

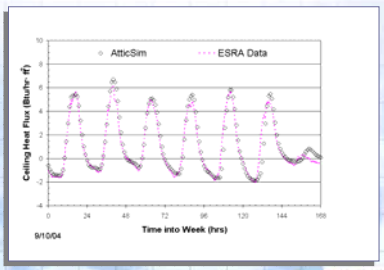
Tile Roofs Being Field Tested for the Tile Roofing Institute

MonierLifetile Concrete Slate Tile Installed on Batten and Counter Batten, Standard Color

Concrete Slate Tile Yields Comparable Performance to Asphalt Shingle with CRCMs



AtticSim Validation against Asphalt Shingle (SR09E89) Attic Assembly



2.6.3 Next Steps

- **Validation of AtticSim code**
  - Direct nailed shingle steep-slope assembly
  - Concrete Tile with venting between deck and roof tile
- **Completion Milestone of 10/01/05 for CEC and Tile Roofing Institute (TRI)**

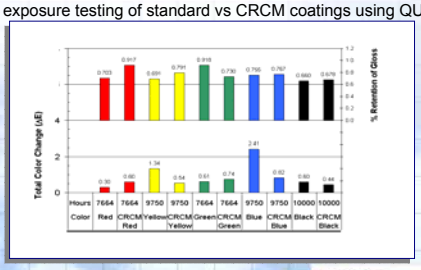
2.6.4 Product Useful Life

- Objective: Investigate the effect of reflectance on the useful life of roofing products and measure the pertinent mechanical and rheological properties to assess the sustainability of the different roofing products
- Deliverables:
  - Solar Reflectance Report
- Schedule: 5/1/04 – 6/1/05→10/1/05
- Funds Expended 40 %

2.6.4 Product Useful Life Analysis

Fade Resistance & Gloss Retention of Painted Metals

- QUV exposure testing of standard vs CRCM coatings using QUV 313B



BASF

2.6.4 Next Steps

- Mechanical Property Testing of Shingles
  - Natural exposure at demo field sites
    - » Weathered at Redding demo site (2 yrs)
  - New shingles with CRCMs
    - » Weatherometer testing (partners)

2.7 Tech Transfer

- Akbari, H. 2005. Heat island reduction: an effective air pollution control strategy paying for itself in energy cost savings. A presentation at the Sierra club meeting, Stockton, CA, Jan. 24.
- Akbari, H., A.A. Berhe, R. Levinson, S. Graveline, A.H. Delgado, and R.M. Paroli. 2005. Aging and weathering of cool roofing membranes. To be published at the RCI Foundation conference, "Cool Roofs: Cutting through the glare." Atlanta GA. May 12-13.
- Akbari, H. and André Desjarlais. 2005. Cooling down the house: Residential roofing products soon will boast *cool* coatings. To be published in *Professional Roofing*.
- Levinson, R., P. Berdahl, and H. Akbari. 2005. Solar spectral optical properties of pigments. To be published at the RCI Foundation conference, "Cool Roofs: Cutting through the glare." Atlanta GA. May 12-13.

2.7 Tech Transfer (Continued)

- Levinson, R., P. Berdahl, and H. Akbari. 2005. Solar spectral optical properties of pigments—Part I: model for deriving scattering and absorption coefficients from transmittance and reflectance measurements. *Solar Energy Materials & Solar Cells* (in press).
- Levinson, R., P. Berdahl, and H. Akbari. 2005. Solar spectral optical properties of pigments—Part II: survey of common colorants. *Solar Energy Materials & Solar Cells* (in press).
- Miller, W.A. 2005. Experimental analysis of the natural convection effects observed within the closed cavity of tile roofs. To be published at the RCI Foundation conference, "Cool Roofs: Cutting through the glare." Atlanta GA. May 12-13.

2.7 Tech Transfer (Continued)

- Akbari, H. 2004. Cool colored roofs to save energy and improve air quality. A presentation at the CONSTRUCTION CHEMICALS OUTLOOK *2004.* Philadelphia, PA. Dec. 9-10.
- Akbari, H. 2004. Cool colored materials for roofs. Presented at the Emerging Technologies in Energy Efficiency-Summit 2004. Hilton San Francisco • San Francisco, CA October 14-15.
- Akbari, H. 2004. Mitigating summer heat islands. Presented at an ICLEI-sponsored conference, San Diego, CA, Sep. 30.
- Akbari, H., R. Levinson. 2004. Coatings for cool vehicles. A presentation at the Ford Motor Company, Detroit, MI. Nov. 18.
- Miller, W. A., Desjarlais, A.O., Akbari, H., Levinson, R., Berdahl, P. and Scichili, R.G. 2004. Special IR reflective pigments make a dark roof reflect almost like a white roof. In Thermal Performance of the Exterior Envelopes of Buildings, THERM IX, Clearwater, FL., Dec.

THANKS TO ALL OF YOU

Industrial Partners & PAC Members for PIER Cool Roofs Project

Cool Colors Project Website

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

http://CoolColors.LBL.gov

Attachment 7

Industry Partners Presentation Materials

3M Cool Roofing Granules

California Energy Committee
PAC Meeting
March 3, 2005

Cool Roofing Granules

3M, LBNL, and ORNL have been collaborating in the area of Cool Roofing since 1995

Why granules?

Shingle Market
- Most widespread residential roofing choice
- High consumer awareness and acceptance
- Shingle roofing costs are lower than most other alternatives

Cool Roofing Granules

- Roofing Granules
  - Weight
  - UV-Protection
  - Aesthetics
- Roofing granules comprise the vast majority of visible surface area on a shingle
- To achieve shingle reflectance values, granules must be reflective

Project Objectives

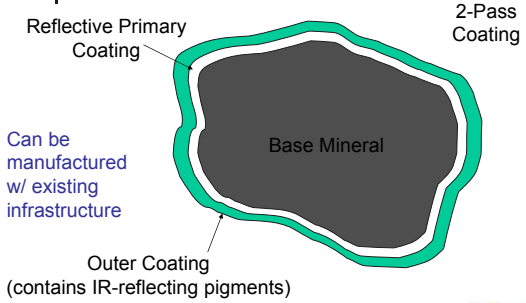
- Ultimate goal is to produce reflective granules that allow shingle manufacturers to produce reflective shingles
- The ideal way to accomplish this is to make the granules/shingles as white as possible
- For consumers, bright white shingles are not desirable aesthetically
- CEC/LBNL Program to develop cool colored roofing materials
  - Infrared reflecting pigments – absorb energy in the visible portion of the solar spectrum

Developmental Approach

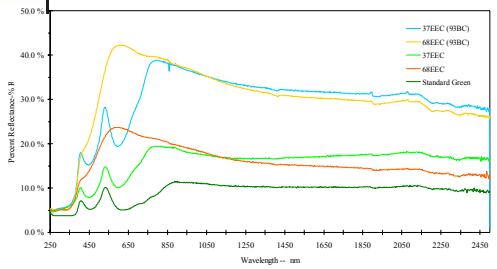
• Have evaluated the following issues:

- Pigments (loadings, IRR) – expensive!
  LBNL Pigment database
- Coating(s)
- Asphalt Effects (~2-3% ↓)
- Granule Grade Effects
- Coverage Effects
- Post-treatment

Developmental Approach



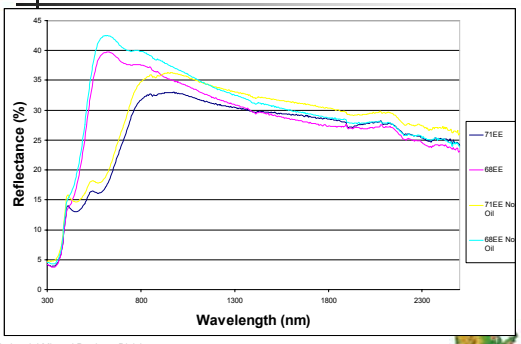
Reflectance Comparison



Air Mass 1.5 Hemispherical 37 Deg. Solar Reflectivities				
37EEC (White Basecoat)	37EEC (No Basecoat)	Standard Green	68 EEC 1 (White Basecoat)	68 EEC (No Basecoat)
27.92	14.48	8.17	33.84	18.54

Air Mass 1.5 Direct Normal 37 Deg Solar Reflectivities				
37EEC (White Basecoat)	37EEC (No Basecoat)	Standard Green	68 EEC 1 (White Basecoat)	68 EEC (No Basecoat)
28.98	14.98	8.45	34.44	18.66

Post-Treatment Effects



Post-Treatment Effects

Weatherometer Testing - 600 Hours

- Xenon Arc => 102 min. @ 63°C, 18min. light plus water spray
- QUV (Fluorescent) => 5 Hrs at 37°C, 1 Hr dark with condensation

Difference in Averages								
	Xenon 3-1				QUV			
Sample #	1	2	3	4	5	6	7	8
	top	top	top	top	top	top	top	top
	0.009	0.015	0.000	0.009	0.004	0.010	0.007	0.003
	bottom	bottom	bottom	bottom	bottom	bottom	bottom	bottom
	0.009	0.007	0.010	0.010	0.006	0.005	0.004	0.005
	Xenon 3-1				QUV			
Sample #	9	10	11	12	13	14	15	16
	0.007	0.007	0.005	0.008	0.006	0.008	0.009	0.008

Cool Granule Products

5 Cool Granule Colors – Solar Reflectance
Cool Tan – 32%
Cool Brown – 25%
Cool Blue Grey – 27%
Cool Grey – 27%
WA9300 White – 29%

Conclusions

- Dark mineral color and granule roughness (multiple scattering events) detracts from reflectance potential
- Multipass coatings and infrared-reflecting pigments can improve relative granule reflectances
  - Resultant granule colors not as rich as standard granules
  - Process/pigments adds significantly to the cost
- Higher reflectance values can be achieved
  - Additional cost is added
  - Aesthetics further degraded
- Continuing research to generate further advances
  - Current approach provides best balance of competing factors

Future Plans

- Future Directions
  - Optimize coating technology
  - Accelerate Agency (CRRC, Energy Star) qualifications
  - Develop relationship between granule reflectance values and ultimate shingle reflectances – coating analogy
  - Collaborate to quantify savings potentials of reflective granule/shingle products

Elk Cool Shingle

CEC PAC Meeting
March 3, 2005
Lou Hahn, Elk Corporation

Elk Cool Shingle

- Three Key Parameters:
  - Performance
  - Aesthetics (Color)
  - Cost
- Goal is to achieve the proper balance.

Elk Cool Shingle

- Cool Shingle Performance
  - Must meet all current performance requirements of an asphalt shingle.
    - ASTM Test Standards
    - Elk internal standards
  - Must meet technically achievable energy saving targets.
    - Energy Star
    - CRRC
    - California Title 24

Elk Cool Shingle

- Factors that affect shingle reflectivity
  - Granule angularity causes cross reflectance
  - Asphalt background – minor (3%)
  - Necessity for double coating granules impacts
    - Cost
    - Color

Elk Cool Shingle

- Shingle Aesthetics-
  - Color must be other than white.
  - Dimensional appearance must be maintained – laminated shingle.
  - Must be attractive to the consumer.
  - Must be compatible with other building design elements.

Elk Cool Shingle

- Cost
  - Must be affordable to the consumer.
  - Provide demonstrable energy savings (lower utility bills) to the home owner.
  - Provide overall economic benefits due to reduced energy consumption.
    - Fewer brownouts.
    - Fewer power plants.
    - Rebates

Elk Cool Shingle

- Cool Shingle Performance Results
  - As-manufactured properties are equivalent to conventional products.
  - Durability including color appears to be equivalent to current products.
  - Solar reflectance values greater than 25% have been achieved with colored shingles.
  - Instrumented panels installed at ORNL.
  - Instrumented test roofs constructed in Redding, California.

Elk Cool Shingle

- Shingle Aesthetics
  - Four initial colors were selected – two different shingle designs.
  - The first is based on Weatheredwood – the most popular shingle color nationwide.
  - All four colors are distinctive and non-white.
  - The appearance on the roof should be very acceptable to the consumer.

Elk Cool Shingle

Elk Cool Shingle

Elk Cool Shingle

- Summary
  - Elk is strongly committed to the concept of energy saving roofing products and believes that cool asphalt shingles have a vital role to play in the steep slope marketplace.
  - Elk has introduced four cool-colored shingle products to the marketplace.

Elk Cool Shingle

- Future Development for the Industrial Partners Team:
  - Continue working with the labs to produce colored cool shingles at attractive cost
  - Finalize the use of the Devices and Services Solar Spectrum Reflectometer (ASTM C1549) for all shingle reflectance testing.
  - Software to estimate the cooling energy savings and peak demand reduction achieved by installing cool shingles on specific buildings
  - Monitor the solar reflectance and color change of the shingles installed at the California weathering sites
  - Monitor the solar reflectance, color change, and thermal performance of shingles at ORNL test facilities

Development of Cool Colored Roofing Materials: Collaboration between ISP Minerals, LBNL, and ORNL

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

Presented by Ingo B. Joedicke
Chief Scientist, ISP Mineral Products

History of ISP/LBNL Collaboration

- **Began in 1994**
- **ISP Resources:**
  - **Granule Manufacturing Expertise**
  - **Lab/Pilot Plant Facilities**
  - **Accelerated and Natural Weathering**
  - **Test Shingles (GAF)**
- **LBNL Resources:**
  - **Technical Expertise**
  - **Reflectivity Measurements**
- **Baseline: Characterize Existing ISP Product Line**

Ultra-Bright White Development

- Various White Pigments Evaluated
- Pigment Loadings Optimized
- Multiple Coatings
- Finer Gradings
- A-707 Developed (TSR = 50)
- Ultra-Bright Pastel Colors
- Use to Increase Reflectivity of Light Blends

Example: Cool Light Brown Tile (photographed in sunlight)

standard: R=0.23

cool: R=0.28

R = solar reflectance

Example: Cool Gray Shingle (photographed in sunlight)

standard: R=0.27

cool: R=0.36

R = solar reflectance

Example: Cool Reddish Shingle (photographed in sunlight)

standard: R=0.28

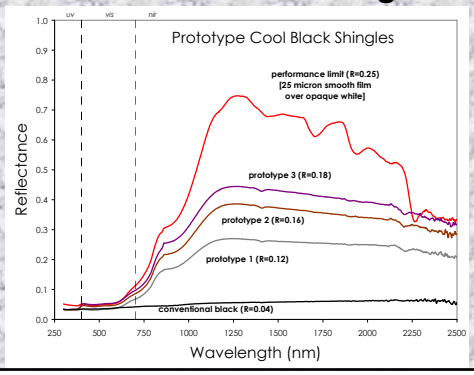
cool: R=0.37

R = solar reflectance

Reflective Dark Granules

- Eliminate “Hot” Pigments
- Incorporate IR-Reflective Pigments
- Maximize Coating Coverage
  - High Pigment Loadings
  - Multiple Coatings
- Reflective Undercoats
  - e.g., Use with Perylene Pigments

Example: Development of Cool Black Shingles



Tasks Completed

- **Developed Ultra-Bright Whites and Pastels**
- **Developed Reflective Dark Granule Prototypes**
- **Prepared 200 Experimental Roofing Granule Samples for LBNL Characterization**
- **Prepared Demonstration Shingles with Reflective Blends**
- **Provided Non-Proprietary Information about the Manufacture of Colored Granules**
- **Reviewed Reports Prepared by LBNL Staff and Provided Comments**

Current and Future Work

- Continue Efforts to Increase Reflectivity and Reduce Costs
- Work with Project Team to Identify New Materials and Techniques
- Establish Test Roofs
- Expand to Large-Scale Demonstrations
- Review Pigment Database – Need to Expand
- Evaluate Coating Formulation Software
- Determine Weathering Benefits of Cool Roofing
- Need Tools to Accurately Measure Solar Reflectance of Manufactured Shingle

Development of Cool Colored Roofing Materials
Project Advisory Committee Meeting
Collaboration of Ferro, Industrial Partners, LBNL & ORNL
Sponsored by: California Energy Commission
March 03, 2005

1

Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

What's been the response to "Cool Roofing" in the Marketplace?

2

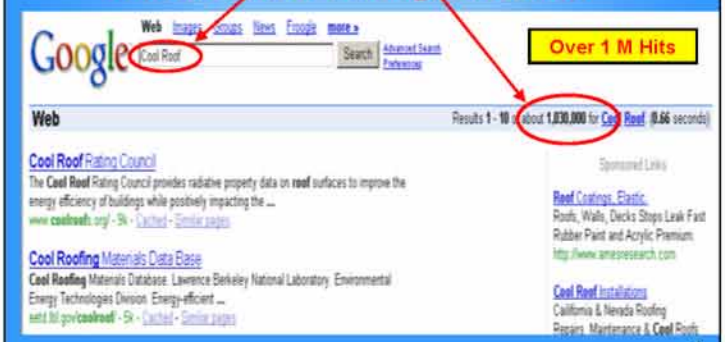
Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

March 2003 Google Search

3

Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

October 2004 Google Search



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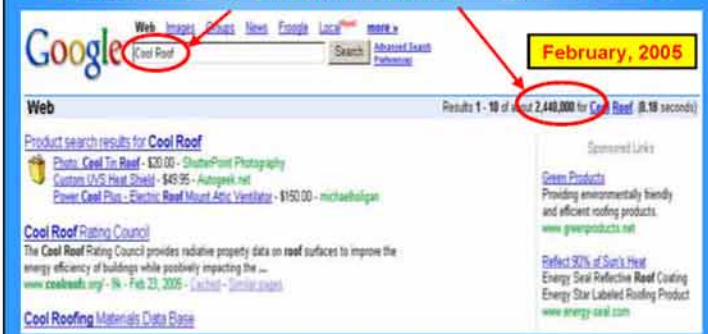
Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

Less than 6 months later – 2.4 M Hits



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Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

History and Development

- Work began in 1999
- Immediate interest from metal roofing industry
- Ferro approached ORNL & LBNL with concept
- PAC formation
- Testing of Cool-Colored metal roofing products
- Promotion into other market segments

6

Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

Areas of interest

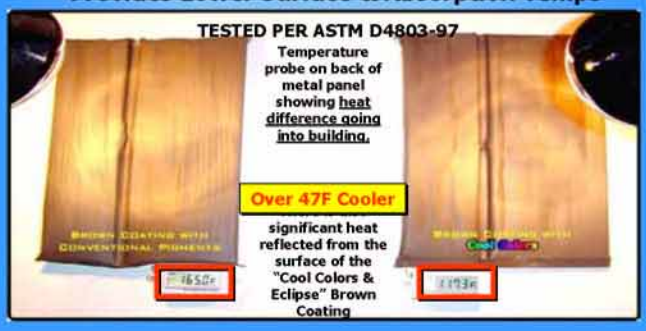
- Metal Roofs and Sidewalls (Coil Coatings)
- EPDM, Single Ply, and Tile Roofing
- Asphalt Shingles (Largest Roofing Market sector)
- Decking (Wood, Concrete and Plastic Composite)
- Concrete (Roof tile, Swimming Pool Deck, Flat Tile)
- Vinyl Siding for homes
- Window frames (profiles)
- Automotive parts
- Cedar Shakes

Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

What are some positive aspects of the technology?

Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

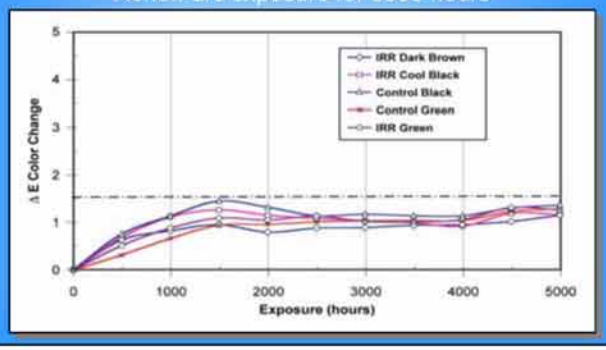
Higher Reflectance in the IR Region Provides Lower Surface & Absorption Temps



Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

Durability –Fade Resistance

Xenon-arc exposure for 5000 hours



Cool Colors™ & Eclipse™
IR Heat & Energy Saving Pigments

What Needs to be done

- Large Scale demonstrations showing $ and KWH savings
- Software to estimate the Cooling Energy Savings
- Value of technology to lessen Peak Energy Demand
- Monitor Color and Reflectivity change over time
- Work with labs on reflectivity improvement
- Monitor thermal performance over time
- Develop predictive software for Cool Coating Design

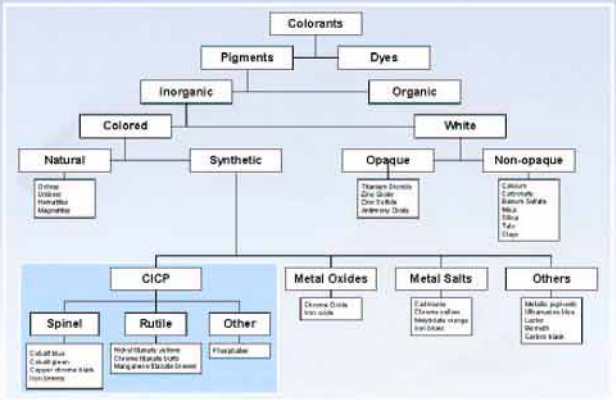
The Shepherd Color Company

Over 70 years' experience

- Based in Cincinnati, Ohio, USA
- Established 1916
- Family Fourth Generation

1

Pigment Classification System



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Markets Served

- Roofing granules
- Metal building products
- Vinyl siding, Windows, Doors
- Automotive
- Wood coatings
- Military

ARCTIC Infrared Reflective Pigments

3

Shepherd The Shepherd Color Company

Attributes

- Heat Stable
- Weather Resistant
  - Samples placed at CA exposure sites
  - Offer to provide Accelerated weathering time
- Chemical Resistance
- Acid Rain & Salt Spray Resistant
- Compatibility

ARCTIC Infrared Reflective Pigments

4

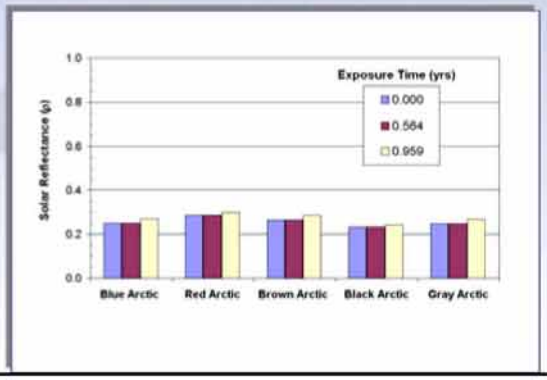
Shepherd The Shepherd Color Company

Concrete and Clay Tile and Painted Metals under exposure

Clay and Painted Metal exposed for 1½ years

5

Concrete Samples Exposed in Sacramento, CA.



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"Cool" Activities

- Associations
  - NCCA
  - CMRC
  - PAC
- Tradeshows
  - NRCA, WSRCA
  - Metalcon, ICE
  - CSI
  - NPE, ANTEC, VSI

ARCTIC Infrared Reflective Pigments

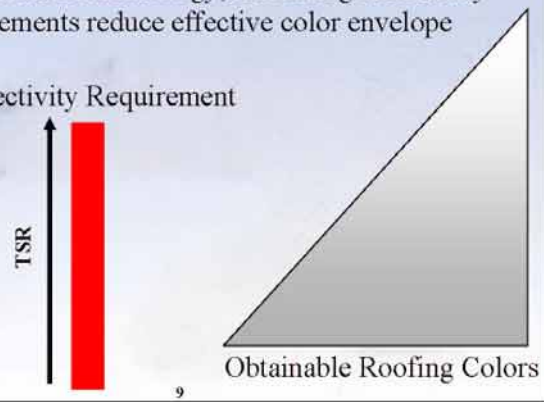
Shepherd The Shepherd Color Company

Market Education

- Publications
- Literature

Color Choice

- Even with IR technology, increasing reflectivity requirements reduce effective color envelope



Shepherd: View of Future

Research Direction: Market Focus

- Cooperate with LBNL, ORNL, Industry to improve reflectance of roofing materials
- Things that work and are durable
  - darker colors / higher TSR
- Increasing reflectance to 40% - number of color choices drops considerably
- Shepherd active R&D to push pigment technologies; Darker, Jetter, Higher TSR
- Overcoming inertia of downstream customers
- Continue to exhibit / promote "Arctic" cool technologies

ARCTIC Infrared Reflective Pigments

Shepherd The Shepherd Color Company

Development of Cool Colored Roofing Materials

Collaboration between BASF, Steelscape, Custom-Bilt Metals, LBNL and ORNL

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

Cool Metal Roofing – A Timeline

- *Early 2001* – BASF acquires cool pigment samples and begins research on incorporating them into PVDF formulas
- *Summer 2001* – BASF introduces "cool roof" to Steelscape and Custom Bilt. BASF creates new product line called ULTRA-Cool. Communication and sample exchange with LBL and ORNL begins. BASF becomes first coil coating producer to join ENERGY STAR roofing program.
- *Fall 2001* – BASF commercially launches UTLRA-Cool at Metalcon.
- *Early 2002* – Custom Bilt begins changing all traditional formulations to "cool".
- *Spring 2002* – First ULTRA-Cool project is built at the Bandon Dunes Golf Resort. Cool Colored Roofing Materials project is launched; BASF and Custom Bilt join as partners.
- *Summer 2002* – Other end-users begin transitioning to ULTRA-Cool.
- *Fall 2002* – Other coil coating manufactures begin introducing cool product lines. Cool Metal Roofing Coalition is formed to coordinate cool roof activities and educate public.
- *2003* – Work continues with LBL/ORNL as well as conversion of end-users to cool roof systems.
- *2004* – Steelscape joins project as a partner and launches their own cool roof paint system; Spectrascape MBM. To date Steelscape has approximately 150 cool colors in production.

Activities in Support of Project

BASF

- Shared non-proprietary research results on cool formulations.
- Prepared films for optical measurements and provided wet samples of ULTRA-Cool. Developed over 100 samples.
- Supplied coating mixing and application equipment.
- Provided accelerated weathering test results.
- Evaluation of the coating formulation software

Custom Bilt

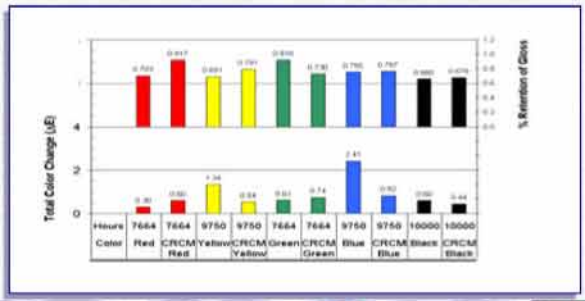
- Provided manufacturing process information.
- Shared market data and sales strategies.
- Supplied roofs for test homes in Sacramento as well as roof sections for testing at ORNL.

Steelscape

- Provided metal samples as needed, both bare and painted.
- Supplied detailed information on the coil coating process.

Product Testing

Fade Resistance & Gloss Retention of Painted Metals

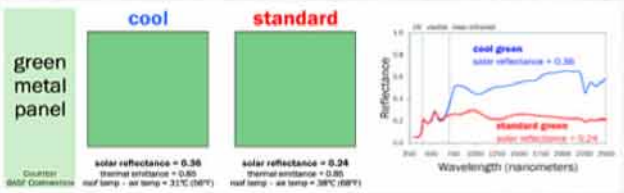


Product Testing

- Accelerated and outdoor performance monitoring of cool formulations continues.
- To date the cool formulation have met or exceeded the color and gloss retention of their "non-cool" counterparts.

Examples of Cool Metal Samples

- Cool green 12 ºF cooler than standard green



Case Study: Baggett vs. Poole Elementary Schools

Two schools, same design, both in GA

Baggett – Standard Evergreen 12% SR

Poole – Cool Evergreen 29% SR

Actual Greystone Power electric bill monitored for one year.

steelscape BASF

Elementary School Study Results

Baggett Elementary (NON)
90,000 S.F. Evergreen

Poole Elementary
90,000 S.F. Evergreen

Greystone Power (Electric) for 2004
Provided by Paulding County Superintendent of Construction
Actual Invoices as provided

May	5,150.27	4,505.25
June	5,887.38	4,206.21
July	5,607.64	4,779.60
Aug	5,394.87	4,339.41
Sep	4,988.06	5,135.07
TOTAL	**$28,043.00**	**$22,965.00**

1st Year Savings
$8,803
Projected 20 Year Savings
$101,650

8

steelscape BASF

C-Style Homes Finished with Painted Metal Shingles and Stucco

House-2 4983 Mariah Place

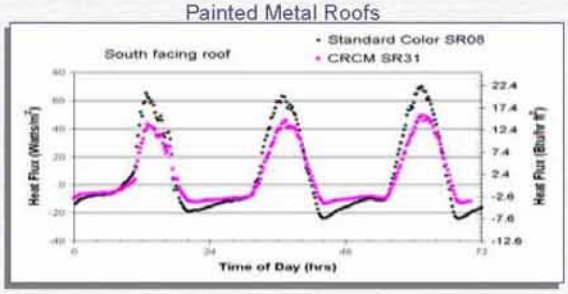
House-4 4991 Mariah Place

Continued real world monitoring of energy use is critical to gaining wider acceptance of cool roofs!

steelscape BASF

Cool Coating Reduces Heat Flux Through South Facing Roof Deck

Painted Metal Roofs



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steelscape BASF

Moving Forward

Although cool roofs are beginning to gain market share and the public is starting to understand the concept, there is still a lot of work to be done . . .

- Software to estimate the cooling energy savings and peak demand reduction achieved by installing cool roofs on specific buildings.
- Monitor the solar reflectance and color change of the materials installed at the California weathering sites.
- Monitor the solar reflectance, color change, and thermal performance of materials at ORNL test facilities and the Sacramento test homes.
- Continue expanding cool coating database.
- Develop predictive software for design of cool coatings.
- Large-scale demonstration.
- Education of architects, specification writers and consumers.

11

steelscape BASF

Development of Cool Colored Roofing Materials

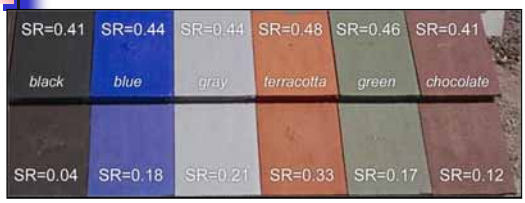
Collaboration between ARC, LBNL and ORNL

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

History of Research & Collaboration

- Began 11-1-2001 under ESIG Grant 52506A /01-20 to study cool coatings with aid of Hashem Akbari and Ronnen Levinson LBNL. Report submitted February 2, 2004.
- ARC explored many cool pigment coatings & selected seven to develop and promote which offer wide color palette.
- ARC tested cool coatings in Southern California at Riverside Public Utilities on model buildings and demonstrated 5-7% savings in energy.
- ARC is testing cool coatings in Sacramento on houses in conjunction with Hanson Roofing and ORNL.
- ARC has trademarked these as COOLTILE IR COATINGS™ and is promoting them in eco-structures March/April issue.
- ARC is actively promoting these cool coatings to tile manufacturers with the intent of selling them on the OEM use of such cool products.

COOL TILE IR COATING™ Applied to Hanson Tile on 2nd A-Style Home



- COOL TILE IR COATING™ technology was developed by Joe Reilly of American Rooftile Coatings

Product Testing on Model House in Southern California (RPU)

A-Style Homes Finished with Hanson Roof Tile and Stucco

House-1 4979 Mariah Place

House-3 4987 Mariah Place

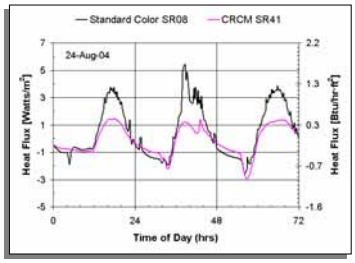
Cavalli Hills Roof Before Coating

Cavalli Hills After Coating

7

Cool Coating Reduces Heat Flux Through Ceiling

Hanson Tile Roofs



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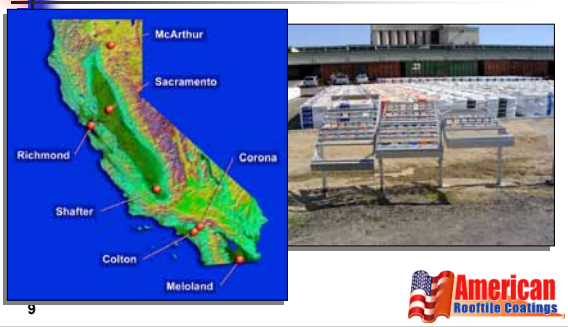
Concrete and Clay tile and Painted Metals under exposure

Clay and Painted Metal exposed for 1½ years



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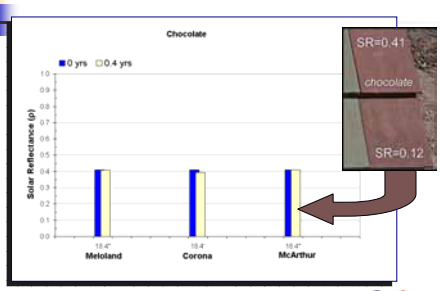
Concrete Tile Coatings under exposure at all seven weathering sites



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Eagletile Tiles with ARC Cool Coatings

11

MonierLifetile™ Black over White

12

ARC Ad for *eco-structure*

Research Issues

- Improving the reflectance of our coatings by including new functional pigments.
- Instruments to measure the solar reflectance of colored concrete tiles in the field on curved surfaces.
- Tools to estimate the cooling energy savings and peak demand reduction achieved by installing cool coatings on specific buildings. ARC believes real savings will exceed 5-7% seen for model buildings.

Research Issues (continued)

- Monitor the solar reflectance and color change on roof materials installed at the California weathering sites
- Testing the solar reflectance, color change, and thermal performance of roofing materials at ORNL test facilities
- Market deployment and large-scale demonstration; this could be driven by rebate or tax credit incentives.