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October 12, 2004

To: Chris Scruton (CEC)
From: Steve Wiel
Subject: **Cool Roof Colored Materials**: Monthly Progress Report for September 2004
CC: Hashem Akbari, Paul Berdahl, Andre Desjarlais, Bill Miller, Ronnen Levinson

A summary of the status of Tasks and Deliverables as of September 30, 2004 is presented in Attachment 1.

HIGHLIGHTS

- The 5th PAC meeting was held at ORNL to discuss project progress so far with LBNL/ORNL working with 12 companies (shingle/granule manufacturers, tile/tile coatings, metal/metal coatings, and pigment manufacturers) to produce prototype roofing products of over 120 shingles, 30 tiles or tile coatings, and 20 metal panels.; minutes of the meeting is attached.
- We completed Task 2.5.1.

Tasks

1.1 Attend Kick-Off Meeting
This Task is completed.

1.2 Describe Synergistic Projects
This Task is completed.

2.1 Establish the Project Advisory Committee (PAC)
This Task is completed.

2.2 Software Standardization
(No activity.)

2.3 PAC Meetings

The 5th PAC meeting was held at ORNL on September 9, 2004. The industry partners and the project team met on the afternoon of September 8, 2004 and discussed technical issue and coordination related to planning and progress of project tasks.

The minutes of the PAC meeting are attached.

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance

No activity this month. We may characterize more mixtures of nonwhite colors this fall if staffing permits.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings

We discussed design of the coating formulation software with our industrial partners at our September 9 PAC meeting. We continue to improve the mixture model on which our coating formulation software is based, and to develop the optimization algorithm.

2.4.3 Develop a Database of Cool-Colored Pigments

We shared the updated database with another industrial partner.

2.5 Development of Prototype Cool-Colored Roofing Materials

2.5.1 Review of Roofing Materials Manufacturing Methods

Task Completed. The revised paper was distributed to the Industry Partners at the September PAC meeting. We have sent the paper for LBNL publication. Western Roofing Magazine is also reviewing the paper for publication.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials

We characterized the reflectances of a number of new shingle prototypes.

Ferro and the Cedar Shake Bureau are working together trying to make a reflective painted cedar shake that is both fade and fire resistant. Parametric testing with several different concentrations of pigment will be tried while applying fire retardants. Forintek's Fire Research group will check the fire resistance of the test shakes. (See Task 2.6.1 for more detail.)

2.5.3 Accelerated Weathering Testing

During the September PAC meeting, we discussed the Xenon-arc and field exposure data from BASF on the small color shifts for aging of metal roofing materials. Partners mentioned that they have accelerated weathering data and will share it with the project. Chris Gross of 3M Minerals and Ingo Joedicke of ISP Minerals offered to search for shingle data, while Mark Ryan of Shepherd Color will look for clay and concrete tile data.

2.6 Field-Testing and Product Useful Life Testing

Initial validations of AtticSim are very promising; however, work continues to help explain differences observed around solar noon between predicted and measured values.

ORNL personnel are ready to instrument a pair of homes in Redding CA with asphalt shingles with and without cool-colored pigments.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites

Instrumented sandwich panels made of oriented strand board (OSB) were received by Jerry Wagar of Ochoa and Shehan Inc, a residential construction firm located in Redding, CA. Wagar is supervising the building of the pair of homes that will demonstrate asphalt shingle roofing with and without cool-colored pigments. ORNL personnel are awaiting Wagar's notice to come and instrument the two homes for monitoring performance of the roof systems. Wagar expects the homes will be ready about the first week of November.

FERRO Corporation painted several new cedar shakes received from the Cedar Shake Bureau and matched colors suggested by John Goveia of Technical Roof Services. Goveia is offering a pair of existing homes located in Martinez CA for demonstrating cedar shakes with and without cool-colored pigments. Reflectance of the unpainted half

of each of the shakes is surprisingly high (Fig. 1). As example, the solar reflectance of the unpainted shake (bottom left in Fig. 1) is 53% while the painted portion is 59%. The shakes have a naturally occurring high solar reflectance which after several years drops to about 35% (see previous monthly showing solar reflectance for Goveia's shake roof). Therefore, the advantage for adding cool-colored pigments to shake roofing addresses more the improved reliability of the shake to fade resistance and even more importantly the potential improvement in fire resistance. Steve Harris of the Cedar Shake Bureau and Ken Loye of Ferro are working to test whether adding the cool-colored pigments will increase the fire resistance of the shake. Ferro has shipped complex inorganic pigments to Harris to test adding the pigments during the addition of fire retardants. The process places cedar shakes in a small vacuum chamber, and pressurizes the ingredients to about 100 psi for two hours. The work is being performed by Paul Morris at the University of British Columbia. Morris will add the color pigments in concentrations of 10, 20, 30, 40 and 50% by weight to determine the concentration needed to produce satisfactory color coating of the shakes. Harris will then have the painted shakes tested by the Forintek's Fire Research group, an International Accreditation Service, to determine the effects of the color pigments on the fire resistance of the cedar shakes.

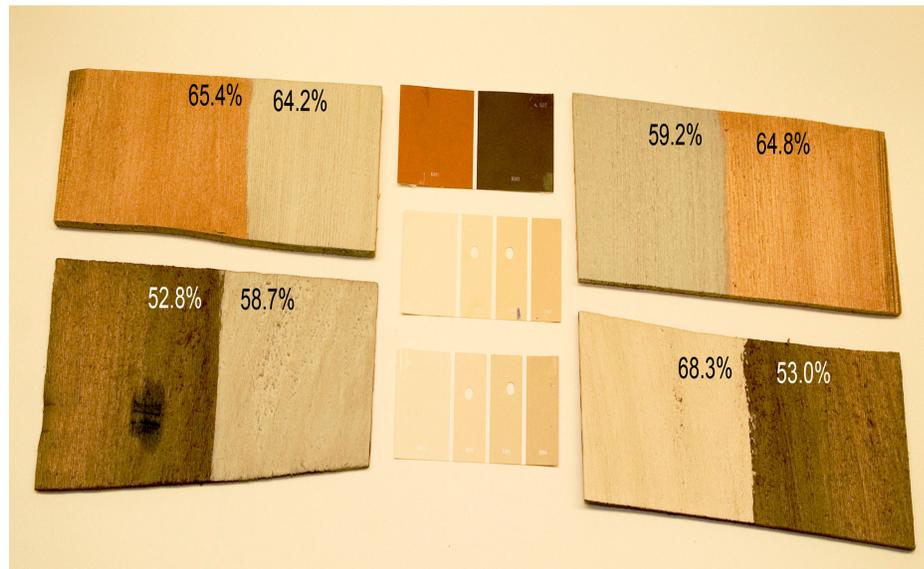


Figure 1. Picture of a new shakes having the interior half of each of the four shakes painted with cool-colored coatings while the exterior half is unpainted. (Goveia provided the color samples).

Wim Boss of SMUD continues to check and trouble shoot the power instrumentation at the Cavalli Hills demonstration homes because our most recent field data showed no power use for the air-conditioners in three of the four homes. Boss discovered that the transducers being used in the field are different from those originally shipped to Campbell Scientific for programming and setup of the data loggers to sense the transducers.

2.6.2 Materials Testing at Weathering Farms in California (No activity)

2.6.3 Steep-slope Assembly Testing at ORNL

Inputs to the AtticSim computer code were developed that describe the geometry and the thermal and moisture characteristics for the ESRA attic test lane having a roof with direct

nailed asphalt shingles. Conduction heat transfer through the south-facing roof deck was modeled by developing conduction transfer functions for the six surfaces of the attic. The transfer functions predict the time-dependent one-dimensional conduction transfer at the interior and exterior surfaces and couples the results with radiation and convection heat transfer within the attic enclosure to predict the heat flux penetrating into the conditioned space.

First efforts to validate the AtticSim model against the direct nailed shingle roof assembly showed excellent agreement to the measured ceiling heat flux penetrating the ceiling of the attic assembly (Fig. 2). However, AtticSim tended at solar noon to under predict the roof's surface temperature and the heat flux penetrating the roof. It also under predicted the attic air temperature. To better check AtticSim, we have installed a pyranometer on the roof to measure rather than calculate the global irradiance normal to the roof. AtticSim uses routines gleaned from DOE2.1e that take the global irradiance and the direct beam irradiance on a horizontal surface and calculate the irradiance normal to the sloped roof. The direct measure of irradiance will enable us to check the solar calculations especially around solar noon where the code under predicts the field data. We are also looking at the ventilation predictions to better understand the magnitude of their effect on the heat transfer analysis, and will attempt to use a tracer gas technique with sulfur-hexafluoride to estimate the air exchange rate in the test attic.

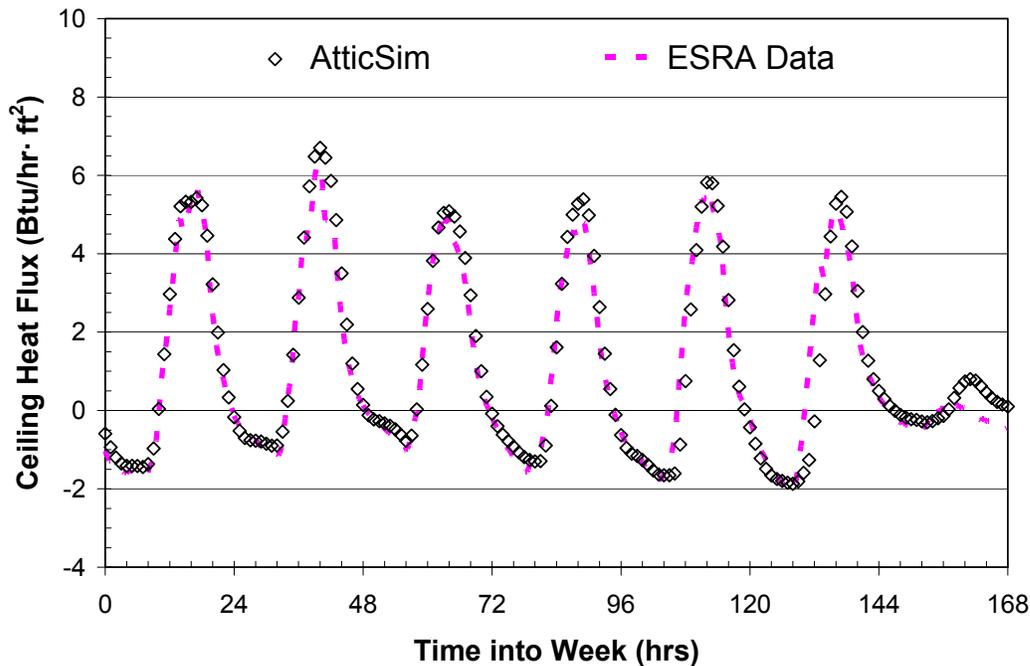


Figure 2. AtticSim validation of the heat flux penetrating the roof deck of the standard production asphalt shingle roof system being field tested on the Envelope Systems Research Apparatus (ESRA).

2.6.4 Product Useful Life Testing

At our recent PAC meeting, we presented a straw-man proposal for an experiment in which asphalt shingles would be artificially aged at 50, 65, and 80 °C (both oven aging and uv + water spray + heat). The stiffness at 0 °C would be monitored as a function of time, and the results would be used to determine how the elevation of temperature affects the results.

There were two criticisms of this proposal. The first is that understanding of stiffness changes over time addresses only one aspect of durability, whereas durability is multi-dimensional. The other criticism of the proposal is that it is very close to what industry has already done, and so little new information would be obtained. (Indeed, the proposal was a follow-up to some excellent papers by the CertainTeed group.) After the PAC meeting, we are considering four options. These include

(1) Focus on literature review and discussions with industrial partners, and summarize what we learn in a review paper. (Whichever option we choose, we are very interested in locating all relevant publications, and in receiving any industry data that can be placed in the public domain.)

(2) Perform some sort of modified experiment. (This option would require concurrence by our industrial partners, which is unlikely unless we come up with a better experimental design.)

(3) Perform some sort of analysis of old shingles exposed at weathering farms. Are the white shingles in better shape than the black ones? What sort of tests need to be done?

(4) Perform some mechanical and/or rheological tests on the new, cooler, asphalt shingles to be demonstrated on the pair of demonstration homes in Redding CA. The manufacturer would pull a shingle from each home about twice a year for a full two years. If successful, these tests would confirm that these new shingles perform in a consistent manner with existing standard shingles.

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

We sent a copy of the “Manufacturing Report” to Western Roofing Magazine for possible publication.

2.7.2 Market Plan

(No activity.)

2.7.3 Title 24 Code Revisions

(No activity.)

Management Issues

- None

Attachment 1

Project Tasks and Schedules (Approved on May 16, 2002)

| Task | Task Title and Deliverables | Plan Start Date | Actual Start Date | Plan Finish Date | Actual Finish Date | % Completion as of 09/30/2004 |
|------|--|-----------------|-------------------|------------------|--------------------|-------------------------------|
| 1 | Preliminary Activities | | | | | |
| 1.1 | Attend Kick Off Meeting <i>Deliverables:</i> <ul style="list-style-type: none"> Written documentation of meeting agreements and all pertinent information (Completed) Initial schedule for the Project Advisory Committee meetings (Completed) Initial schedule for the Critical Project Reviews (Completed) | 5/16/02 | 5/16/02 | 6/1/02 | 6/10/02 | 100% |
| 1.2 | Describe Synergistic Projects <i>Deliverables:</i> <ul style="list-style-type: none"> A list of relevant on-going projects at LBNL and ORNL (Completed) | 5/1/02 | 2/1/02 | 5/1/02 | 5/1/02 | 100% |
| 1.3 | Identify Required Permits | N/A | | N/A | | |
| 1.4 | Obtain Required Permits | N/A | | N/A | | |
| 1.5 | Prepare Production Readiness Plan | N/A | | N/A | | |
| 2 | Technical Tasks | | | | | |
| 2.1 | Establish the project advisory committee <i>Deliverables:</i> <ul style="list-style-type: none"> Proposed Initial PAC Organization Membership List (Completed) Final Initial PAC Organization Membership List PAC Meeting Schedule (Completed) Letters of Acceptance | 6/1/02 | 5/17/02 | 9/1/02 | | 100% |
| 2.2 | Software standardization <i>Deliverables:</i> <ul style="list-style-type: none"> When applicable, all reports will include additional file formats that will be necessary to transfer deliverables to the CEC When applicable, all reports will include lists of the computer platforms, operating systems and software required to review upcoming software deliverables | N/A | | N/A | | |

Project Tasks and Schedules (contd.)

| Task | Task Title and Deliverables | Plan Start Date | Actual Start Date | Plan Finish Date | Actual Finish Date | % Completion as of 09/30/2004 |
|-------|--|-----------------|-------------------|------------------|--------------------|-------------------------------|
| 2.3 | <p>PAC meetings <i>Deliverables:</i></p> <ul style="list-style-type: none"> • Draft PAC meeting agenda(s) with back-up materials for agenda items • Final PAC meeting agenda(s) with back-up materials for agenda items • Schedule of Critical Project Reviews Draft PAC Meeting Summaries • Final PAC Meeting Summaries | 9/1/02 | 6/1/02 | 6/1/05 | | 83% (5/6) |
| 2.4 | Development of cool colored coatings | | | | | |
| 2.4.1 | <p>Identify and Characterize Pigments with High Solar Reflectance <i>Deliverables:</i></p> <ul style="list-style-type: none"> • Pigment Characterization Data Report | 6/1/02 | 6/1/02 | 12/1/04 | | ~97% |
| 2.4.2 | <p>Develop a Computer Program for Optimal Design of Cool Coatings <i>Deliverables:</i></p> <ul style="list-style-type: none"> • Computer Program | 11/1/03 | 11/1/03 | 12/1/04 | | ~65% |
| 2.4.3 | <p>Develop a Database of Cool-Colored Pigments <i>Deliverables:</i></p> <ul style="list-style-type: none"> • Electronic-format Pigment Database | 6/1/03 | 7/1/03 | 6/1/05 | | ~65% |
| 2.5 | Development of prototype cool-colored roofing materials | | | | | |
| 2.5.1 | <p>Review of Roofing Materials Manufacturing Methods <i>Deliverables:</i></p> <ul style="list-style-type: none"> • Methods of Fabrication and Coloring Report | 6/1/02 | 6/1/02 | 6/1/03 | | ~99% |
| 2.5.2 | <p>Design Innovative Methods for Application of Cool Coatings to Roofing Materials <i>Deliverables:</i></p> <ul style="list-style-type: none"> • Summary Coating Report • Prototype Performance Report | 6/1/02 | 6/1/02 | 12/1/04 | | ~90% |
| 2.5.3 | <p>Accelerated Weathering Testing <i>Deliverables:</i></p> <ul style="list-style-type: none"> • Accelerated Weathering_Testing_Report | 11/1/02 | 10/1/02 | 6/1/05 | | ~18% |

Project Tasks and Schedules (contd.)

| Task | Task Title | Plan Start Date | Actual Start Date | Plan Finish Date | Actual Finish Date | % Completion as of 09/30/2004 |
|-------|---|-----------------|-------------------|------------------|--------------------|-------------------------------|
| 2.6 | Field-testing and product useful life testing | | | | | |
| 2.6.1 | Building Energy-Use Measurements at California Demonstration Sites <i>Deliverables:</i> <ul style="list-style-type: none"> • Demonstration Site Test Plan • Test Site Report | 6/1/02 | 9/1/02 | 10/1/05 | | 80% |
| 2.6.2 | Materials Testing at Weathering Farms in California <i>Deliverables:</i> <ul style="list-style-type: none"> • Weathering Studies Report | 6/1/02 | 10/1/02 | 10/1/05 | | 65% |
| 2.6.3 | Steep-slope Assembly Testing at ORNL <i>Deliverables:</i> <ul style="list-style-type: none"> • Whole-Building Energy Model Validation • Presentation at the Pacific Coast Builders Conference • Steep Slope Assembly Test Report | 6/1/02 | 10/1/02 | 10/1/05 | | 65% |
| 2.6.4 | Product Useful Life Testing <i>Deliverables:</i> <ul style="list-style-type: none"> • Solar Reflectance Test Report | 5/1/04 | 5/1/04 | 6/1/05 | | 12% |
| 2.7 | Technology transfer and market plan | | | | | |
| 2.7.1 | Technology Transfer <i>Deliverables:</i> <ul style="list-style-type: none"> • Publication of results in industry magazines and refereed journal articles • Participation in buildings products exhibition, such as the PCBC Brochure summarizing research results and characterizing the benefits of cool colored roofing materials | 6/1/03 | 6/1/02 | 6/1/05 | | ~55% |
| 2.7.2 | Market Plan <i>Deliverables:</i> <ul style="list-style-type: none"> • Market Plan(s) | 5/1/05 | | 6/1/05 | | |
| 2.7.3 | Title 24 Code Revisions <i>Deliverables:</i> <ul style="list-style-type: none"> • Document coordination with Cool Roofs Rating Council in monthly progress reports • Title 24 Database | 6/1/02 | 5/16/02 | 6/1/05 | | ~10% |

Project Tasks and Schedules (contd.)

| Task | Task Title | Plan Start Date | Actual Start Date | Plan Finish Date | Actual Finish Date | % Completion as of 09/30/2004 |
|---------|--|-----------------|-------------------|------------------|--------------------|-------------------------------|
| VII | Critical Project Review(s) <i>Deliverables:</i> <ul style="list-style-type: none"> Minutes of the CPR meeting | | | | | |
| XII (C) | Monthly Progress Reports <i>Deliverables:</i> <ul style="list-style-type: none"> Monthly Progress Reports | 6/1/02 | 6/1/02 | 6/1/05 | | 72% (26/36) |
| XII (D) | Final Report <i>Deliverables:</i> <ul style="list-style-type: none"> Final Report Outline Final Report | 3/1/05 | | 10/1/05 | | |
| | Final Meeting <i>Deliverables:</i> <ul style="list-style-type: none"> Minutes of the CPR meeting | 10/15/05 | | 10/31/05 | | |

Attachment 2.

Minutes of the September 9 PAC meeting at ORNL

September 29, 2004

To: Chris Scruton
Project Manager
California Energy Commission

From: Hashem Akbari

Subject: Cool Roof Colored Materials—Minutes of September 9, 2004 PAC Meeting

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

On September 9, 2004 from 9 am to noon, the LBNL/ORNL project staff held at ORNL their fifth 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 nine 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 Project Director, Steve Wiel (LBNL), opened the meeting with some comments on the objectives of the project and the reasons to have PAC meetings (Slides 1-2). 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. Wiel introduced the research team at LBNL and ORNL (Slide 5). Then he asked Akbari to present Tasks 2.4 and 2.5.
- C. Akbari outlined the technical tasks to be discussed at the meeting (Slide 6). He mentioned we have started work on two new tasks in addition to the ongoing tasks. The newly initiated tasks are:
 - Task 2.5.3: Accelerated Weathering Testing, and
 - Task 2.6.4: Product Useful Life Testing.

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). Akbari then asked Levinson to present the details of Subtask 2.4.1, 2.4.2, and 2.4.3.
 1. *Subtask 2.4.1: Identify and Characterize Pigments with High Solar Reflectance* (Slides 8–17). Levinson reported that the Characterization Task is essentially complete and that we have submitted two papers (Levinson, R., P. Berdahl and H. Akbari. 2004. 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. 2004. Solar spectral optical properties of pigments, Part II: survey of common colorants) to *Solar Energy Materials & Solar Cells*. He mentioned recent pigment characterization of paint tints (colors + white) and mixtures of nonwhite paints to develop algorithms to estimate the optical

characteristics of paint mixtures. Levinson mentioned that we initially focused the characterization of equal-volume binary mixtures drawn from a palette of 15 cool colors. That resulted in 105 binary mixtures (equal volume) from which we chose 32 appealing color combinations. We measured the optical characteristics of each mixture over a white and a black background. We have also computed the Kubelka-Munk spectral absorption and scattering coefficients (K and S) for each sample. This characterization will be useful in developing a refined model for coating formulation software (Task 2.4.2). Time permitting, we may also characterize volumetric mixtures of 1:4 and 4:1 for the selected binary paints.

Action Items:

- None.
2. *Subtask 2.4.2: Develop a Computer Program for Optimal Design of Cool Coatings* (Slides 18-28). Levinson gave a brief review of the activities for development of the software (algorithm) for optimal design of cool coatings. He mentioned that the software is anchored on three elements: the pigment property database, theory of mixtures, and an optimization algorithm. The model that is used to characterize paint mixtures is a simple volumetric model where each component contributes volumetrically to absorption K and scattering S of the mix (i.e., $K_{\text{mix}} = \sum c_i K_i$ and $S_{\text{mix}} = \sum c_i S_i$, where c_i is volume fraction of component i). Then he showed examples of K-M characterization of tints and nonwhite mixtures. The preliminary results indicate that the simple volumetric model often fails to estimate the scattering coefficient (S) of the mixtures. During the remainder of the project, we will work to develop a better physical model for paint mixtures.

Action Items:

- None.
3. *Subtask 2.4.3: Cool-colored Material Database* (Slides 29-30). Levinson provided a quick review of the status of the database and mentioned that now our database includes characterization for 233 pigmented coatings. This includes 87 masstone, 57 1:4 tints, 57 1:9 tints and 32 1:1 nonwhite mixtures. Time permitting, we will measure, characterize, and add 1:4 and 4:1 nonwhite paint mixtures to the database.

Action Items:

- None.

Overall discussion of Task 2.4. Levinson answered a few clarifying questions. The group was satisfied with the presentation.

B. Task 2.5: Development of Prototype Cool-Colored Roofing Materials (Slide 31). 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 32-33). Akbari mentioned that the work on this subtask is basically completed. A draft 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 Roof web site (<http://coolcolors.lbl.gov>). Akbari mentioned that the draft report has been reviewed by our industry partners and their comments have been incorporated in the report. The report will be sent out for LBNL publication. The task will be completed upon LBNL publication of the report.

Action Items:

- None.
2. *Subtask 2.5.2: Design Innovative Methods for Application of Cool Coatings to Roofing Materials* (Slides 34-41). 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 manufacturers, tile/tile coatings, metal/metal coatings, and pigment manufacturers) to produce prototype cool colored roofing products. The results have been prototypical production of over 120 shingles, 30 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. The recent effort has focused on development of cool granules using both reflective undercoats (e.g., TiO₂ white) and topcoats with cool-colored pigments identified in Task 2.4.1. Our partners have used the cool granules to produce over 70 new prototypical shingles. Several of the new prototype shingles are of dark to medium color with solar reflectances of 0.20 – 0.36. Akbari continued by providing several examples of cool shingles in dark brown, light brown, gray, and reddish colors. Next steps for this task include improving the solar reflectance of prototype shingles by using cool pigments and increasing the undercoat reflectance. Time-permitting, we will also work with our concrete tile and clay tiles partners to develop cool products.

Action Items:

- None.
3. *Subtask 2.5.3: Accelerated Weathering Testing* (Slides 42-46). Berdahl lead the discussion of this task by reviewing the Task's objective. He showed data for pigment fade resistance (Courtesy of BASF) for several cool colored metal products. The standard test method is to measure the sum of squares of the changes in lightness (ΔL), red/green variations (Δa) and yellow/blue variation (Δb) [i.e., $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$]. The data from accelerated weathering of several samples showed that the fade in materials (ΔE) has been less than 2. He also showed data from three years of field exposure in Florida showing a fade of less than 2. During the remainder of this task, we would collect additional accelerated weathering data from industry partners, integrate them with the data from California weather farms, and prepare a summary report

Action Items:

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

Overall discussion of Task 2.5. Partners mentioned that they have accelerated weathering data and will share it with the project. Chris Gross of 3M Minerals and Ingo Joedicke of ISP Minerals offered to search for shingle data, while Mark Ryan of Shepherd Color will look for clay and concrete tile data.

C. Task 2.6: Field Testing and Product Useful Life Testing (Slides 47). Desjarlais started discussion of the progress on this task by briefly reviewing the task objectives. Miller then present details of individual tasks.

1. *Task 2.6.1: Building Energy Use Measurements at California Demonstration Sites* (Slides 48-56). On the onset of the discussions, Miller stated that the installation of the monitoring equipment in four houses at the Mike Evan's development has been completed and we are currently at the stage of data collection. Miller briefly reviewed the characteristics of the two pair of houses (one with cool roof and one with standard roof) with metal roofs and with tile roofs. On the houses with Hanson tile roofs, the attic temperature on the house with cool roof is about 4 degrees K cooler than the one with standard roof. The heat flux through the roof during the mid day in the house with cool roof is about half that of the house with standard roof. He also showed data on houses with metal roof showing that the heat flux through the south-facing roof in the house with cool roof is about 30% lower than the one with standard roof. During the remainder of the project, we will establish two pair of demonstration sites at Redding, CA (for composition shingles) and Martinez, CA (for cedar shakes).

Discussion of Tasks 2.6.1. There were some clarifying questions and supplemental questions

for Miller. Kalkanoglu asked whether the warranty on cool colored coatings installed on the concrete tile (installed by American Rooftile Coating) covers roof reflectance. Miller responded he will discuss the question with ARC. Kalkanoglu also asked whether the attics of the demonstration houses are ventilated. Miller responded that the attics are naturally ventilated. Brown asked whether the peak demands in the houses are monitored. Miller responded that we have power transducers installed by the Sacramento Municipal Utility District for measuring the total house power and the central air-conditioning unit's power. The field data is just now being collected and will hopefully show the effect of cool roofs on peak demand. We are also planning to monitor peak demand on the upcoming two demonstration houses. Turnbull of PG&E asked what will be the cost effectiveness of the cool roofs. Miller referred to the "Cool Team's" publication "Special Infrared Reflective Pigments Make a Dark Roof Reflect Almost Like a White Roof," which shows predictive cost savings for residential cool roofs. Kalkanoglu also asked how much energy are we referring to and what impact will it have on the state's utility load.

Action Items:

- None.
2. *Subtask 2.6.2: Materials Testing at Weathering Farms in California* (Slides 58-60). Miller mentioned that all samples have been installed at the seven weathering farms in California and we have collected weathering data for about one year. Samples from Joe Riley have been exposed for about 6 months. Miller also showed solar reflectance data for several metal and tile roofing materials.

Discussion of Tasks 2.6.2. Kalkanoglu would like to meet with the project team and discuss the longevity of the cool roof's reflectance. Ming stated that we should figure out ways to inform customers of aging/weathering and of changes in the solar reflectance of cool roofs.

Action Items:

- The project team and Kalkanoglu to discuss the effect of aging on albedo.
3. *Subtask 2.6.3: Steep-Slope Assembly Testing at ORNL* (Slides 61-70). 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 discussed natural air ventilation underneath roof tiles and its effect in cooling the roof. He showed data indicating that the heat flux through the roofs and attics were lowest for mission tile roof (compared to other roofing systems) because of their higher solar reflectance. Miller also briefly discussed potential energy savings from cool roofs. The next steps in the task include (1) validation of the attic simulation (AtticSim) code, (2) visualization of flow through the roof tiles, and (3) preparation of the final task report.

Discussion of Tasks 2.6.3. There were question regarding measuring techniques for natural airflow underneath the roof tiles.

Action Items:

- None.
4. *Subtask 2.6.4: Product Useful Life Testing* (Slides 71-74). Berdahl lead the discussion of this task by briefly reviewing the task's objectives. He mentioned that our efforts have focused on the aging of the asphalt shingles. He briefly reviewed a key article by Certainteed on the mechanism of aging of shingles by the processes of UV damage, oxidation of asphalt, out-diffusion of oils from asphalt, gradual increase in asphaltene contents, and decrease in naphthene aromatics. Thermal stress combined with these changes eventually causes cracking and failure of the asphalt singles. Berdahl then hypothesized and proposed an experiment to

document whether cooler asphalt shingles would stay flexible for longer periods and hence last longer. Then he presented plans for the next steps of the task.

Discussion of Tasks 2.6.3. There were lively questions and discussion on the experiment design. Several manufacturers (Desuto, Wilson and McCaskill) mentioned that the proposed experiment has been already performed. McCaskill believes ARMA must have data to prove the durability claim. The question of relating the solar reflectance to the useful life of the roof is far more complicated than what is proposed in the experiment. It was suggested that the project team consult further with Elk, CertainTeed, and GAF to acquire historical data and better formulate and finalize the experimental plan.

Action Items:

- Berdahl and Miller to consult with Elk, CertainTeed, and GAF to finalize the experimental plan.
5. *Subtask 2.7.1: Technology Transfer* (Slides 75). 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 three articles (an article printed in the September issue of eco-structure magazine, a paper published in ACEEE summer study in August, 2004, and a paper submitted to the conference “Thermal Performance of Exterior Envelopes of Buildings, IX” to be held in December 2004.

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. The industry would like to participate in the 2008 cycle of Title 24 upgrade. Any revisions to the standard should include both the market availability and cost of products.

Kalkanoglu (CertainTeed) asked whether the current calculations and measurements of energy savings have been performed for the living space. Akbari responded that all pervious calculations account for summer time cooling energy savings and potential winter time heating penalties. Most measurements of the energy savings have been performed for summertime cooling season. Shiao (CertainTeed) suggested that software to estimates savings and provide a platform for trade-off calculations is needed.

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.

IV. **Schedules of PAC Meetings and Concluding Remarks (Slides 76-77).** The next meeting is tentatively scheduled for Thursday, March 3, 2005 to be held at one of our industry partners’ facilities (We will confirm the location of the meeting by December 15, 2005). All materials related to the project will be posted to <http://CoolColors.LBL.gov>.

V. **Adjourn.** The PAC meeting adjourned at noon.

**Attendance, Cool Colored Roof PAC Meeting
California Energy Commission, Sacramento, CA
September 9, 2004**

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|-------------------|---------------------------------------|---------------------|
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| McCaskill, John | Elk Corporation | 972-851-0400 |
| Miller, William | Oak Ridge National Laboratory | 865-574-2013 |
| Ryan, Mark | Shepherd Color Co. | 513-874-0714 |
| Shiao, Ming | CertainTeed | 610-341-6431 |
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| Turnbull, Peter | PG&E/CRRC | 415-973-2164 |
| Vondran, Michelle | Steelscape | 909-484-4623 |
| Wiel, Stephen | Lawrence Berkeley National Laboratory | 510-486-5396 |
| Wilson, Paul | Elk Corporation | 972-872-2340 |

- Participated in the PAC meeting through conference call.

**Development of Cool Colored Roofing Materials
Project Advisory Committee Meeting**

9 am to 12:00 pm (EDT)

Thursday, September 9, 2004

Oak Ridge National Laboratory

Oak Ridge, Tennessee

Contact Information: Ms. Gwen Scudder (865-757-4345, scuddergt@ornl.gov)

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

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

IV. Project Updates and Technical Tasks: Review and Discussions (9:20-11:10)

Questions to the PAC: Are we still 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/Berdahl/Levinson) (9:20-9:40)
(mainly Levinson/Berdahl)
 - 1. Identify and Characterize Pigments with High Solar Reflectance (5 min)
 - 2. Develop Software for Optimal Design of Cool Coatings (12 min)
 - 3. Cool Colored Material Database (3 min)
- B. Task 2.5: Development of prototype cool-colored roofing materials (Akbari et al.) (9:40-10:20) (starting with Akbari but Berdahl and Miller to talk about 2.5.3)
 - 1. Updates on Review of Roofing Materials Manufacturing Methods (3 min)
 - 2. Design Innovative Methods for Application of Cool Coatings to Roofing Materials (30 min)
 - 3. Accelerated Weathering Testing (7 min)
- C. Task 2.6: Field-testing and product useful life testing (Miller/Desjarlais/Berdahl) (10:20-11:05) (Starting with Desjarlais, then Miller and continue with Berdahl/Miller on Task 2.6.4.)
 - 1. Building Energy-Use Measurements at California Demonstration Sites (20 min)
 - 2. Materials Testing at Weathering Farms in California (10 min)
 - 3. Steep-slope Assembly Testing at ORNL (5 min)
 - 4. Product Useful Life Testing (10 min)
- D. Technology transfer and market plan (Akbari) (11:05-11:10)

V. Summary, Discussion of Key issues, and Comments from PAC members (11:10-11:55)

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. Schedule for the next PAC meetings and concluding remarks (11:55-12:00)

VII. Adjourn (12:00)

VIII. Lunch (12:00 – 1:00 pm)

IX. Visit to ORNL roof testing facilities (1:00 – 2:30 pm) (Optional)

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Attachment 4.

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Attachment 5.

**Cool Roof Colored Materials
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Welcome PG&E/CRRC and SCE (New PAC members)**

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Attachment 6

Presentation