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July 23, 2004

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

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

HIGHLIGHTS

- We have begun collecting building energy use and temperature data from cool-colored roofs on two demonstration houses in Cavalli Hills.
- The project team prepared and submitted an article titled "Cool Colored Materials for Roofs" for the August 2004 meeting of the American Council for an Energy Efficient Economy (ACEEE).
- The project team prepared and submitted an article on cool roof colored materials for *eco-structure* magazine.
- Review comments have been incorporated in the paper "*Special infrared reflective pigments make a dark roof reflect almost like a white roof*" to be presented in the December 2004 conference "Performance of Exterior Envelopes of Whole Buildings IX (THERM IX)" (Clearwater Beach, FL).
- We continue to work with tile, granule, and shingle manufacturers to develop cooler products.
- Lou Hahn and John McCaskill of Elk Corporation are helping to locate a demonstration site for field testing asphalt shingles on a pair of homes.

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
Minutes of the March 4 meeting were prepared.

Preparation for September PAC meeting is started.

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance
We are working with a Japanese firm to characterize some novel black and gray cool pigments. The cool gray coating received from Japan is very interesting. The composition of the coating is unknown, so we subjected it to x-ray diffraction analysis. The coating contains a mixed metal oxide of iron and chromium, and has been lightened with titanium dioxide (rutile). A third crystalline component was observed but not yet identified.

We continue to develop a model and software predicting the reflectance of paint mixtures.

Our two pigment papers have been submitted to Solar Energy Materials & Solar Cells.

(The papers can be downloaded from
http://coriolis.lbl.gov/~hashem/share/PigmentPropertiesII(survey).pdf

http://coriolis.lbl.gov/~hashem/share/PigmentPropertiesI(model).pdf).

We are preparing a series of nonwhite paint mixtures to test the mixture model used in our software for design of high-reflectance coatings.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings
We continue to develop a model and software predicting the reflectance of paint mixtures.

2.4.3 Develop a Database of Cool-Colored Pigments
We made some improvement to our database.

2.5 Development of Prototype Cool-Colored Roofing Materials

2.5.1 Review of Roofing Materials Manufacturing Methods
We have started revising the June 2003 report to include the summary of manufacturing processes for cool-colored concrete tiles that we received from Jerry Vandewater (MonierLifetile) in February. We have abandoned our effort to visit a wood shake manufacturing plant or obtain literature information for this roofing product. With the revision of the report and submission for publication this task will be completed.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials
We evaluated 35 prototype shingles made with cool granules, and also examined shingles that use conventional (hot) granules, but are sprayed with a cool topcoat. We noted that multiple spectrometer measurements are required to properly characterize the reflectance of shingles with variegated surfaces (e.g., blends).

Our activities this month focused on development of cool shingles. In collaboration with our industry partners, we produced cool dark brown prototype (solar reflectance 0.21) very closely matches a conventional brown shingle (solar reflectance 0.11). We hope to increase the solar reflectance of the prototype to 0.25.

We also examined wood shake products that have been coated with cool paints.

We discussed with our partners the production of sample cool-colored shingles for demonstration. We received two cool shingles to present to the developers of the demonstration houses for their selection.

2.5.3 Accelerated Weathering Testing

Akbari and Berdahl had discussions with our industrial partners about the development of a plan for accelerated testing of cool colored materials.

We completed a literature survey and located a few key papers providing limited data on the aging and weathering of asphalt shingles. (See discussion in Task 2.6.4 below.)

2.6 Field-Testing and Product Useful Life Testing

Negotiations with Daues of Mercy Housing, the “Cool Team” and Elk’s Marketing director John McCaskill were not successful, despite Elk’s offer to donate 220 squares of shingles for two apartment buildings. Daues stated Mercy Housing had subcontracted the roofing to a company that offered very little credit for the donation of shingles. In short, the subcontractor signed an agreement and will not deviate from the agreed upon quotation. Lou Hahn of Elk said he would help the “Cool Team” find another site for testing asphalt shingles with and without cool-colored materials. Ming Shiao of Certainteed also has some experimental shingles with cool-colored pigments but he is not able to provide support for finding a demonstration site. GAF was not willing to participate in the offer of materials.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites

Field data is being acquired from the two A-style homes and one of the two C-style homes having a standard brown painted metal roof. Attic air temperatures are compared for the two A-style homes having concrete tile with and without cool colored roofing materials. Solar reflectance of the tile with the Cool Tile IR Coating™ is about 0.41; tiles with the standard chocolate brown color have a solar reflectance of about 0.08. The higher reflectance roof (SR 41 in Figure 1) reduced the attic temperature about 5 to 15ºF around solar noon. It is also interesting to note that the roof with the Cool Tile IR Coating™ had cooler attic temperatures during the early morning hours, implying that the coating with solar reflectance of 0.41 reduced the amount of energy stored in the concrete as compared to the adjacent house with tile having solar reflectance of only 0.08. This in-turn will cause the air-conditioning unit for the house with Cool Tile IR Coating™ to use less power than the adjacent home with concrete tile of standard color. Power measurements, once on-line, will help show this extra advantage of the cool-colored coatings as applied to the tile roofs.

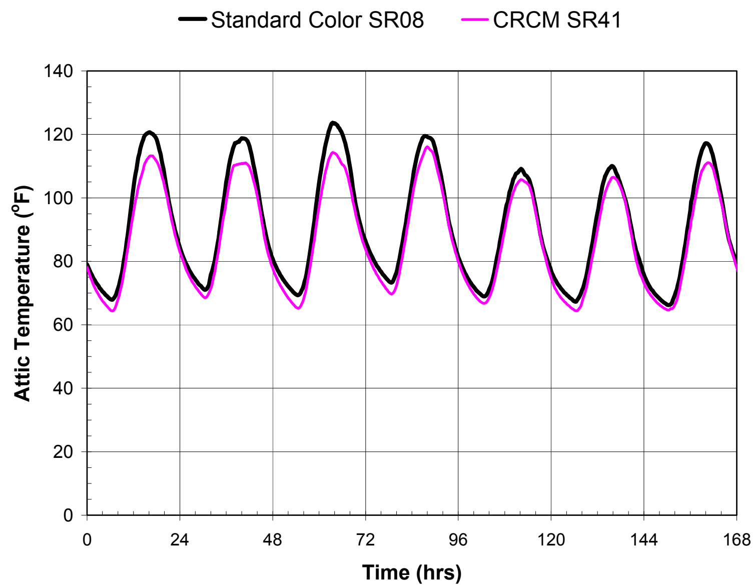

Figure 1. Attic temperatures measured during the week starting June 25, 04 for the two A-style homes with Hanson's low-profile concrete tile.

The reduction in attic temperature is a direct result of the reduction in heat penetrating the roof. Heat flux transducers embedded in the west facing roofs of both A-style homes show that the roof with Cool Tile IR Coating™ had less heat penetrating the roof as compared to the roof with standard color tile. The greatest differences occur around solar noon, which may prove very beneficial for peak load reductions for the electric utilities.

John Goveia of Technical Roof Services, Martinez, CA, offered his own home for demonstrating wood shakes with cool-colored roofing materials. A neighbor adjacent to Goveia's home will also install new wood shakes for making side-by side comparisons. However, fire resistance of the shakes treated with cool colored pigments must be documented for code officials to approve permits for Goveia and his neighbor to install the new roof materials. Steven Harris of the Cedar Shake & Shingle Bureau, sent cedar shakes to Ken Loyle and Bob Blonski of Ferro, who are applying cool colored coatings to the new shakes to make them appear weathered but with high solar reflectance and Class B fire code certification.

2.6.2 Materials Testing at Weathering Farms in California

Joe Riley of American Roof Tile Coatings and ORNL personnel visited the exposure sites in May, made reflectance and emittance measurements and installed concrete and clay tile samples prepared by US Tile, MonierLife Tile and Shepherd Color Co and by Joe Riley.

Solar reflectance and emittance measures were collected for the painted metals and clay tiles being exposed at all weathering sites. All painted metal samples had a very dusty appearance with the worst soiling observed for samples exposed in Colton, which showed the larger loss of reflectance as compared to El Centro and McArthur (Fig. 2). The crisp and clear alpine climate of McArthur showed the lowest loss of reflectance (Fig. 2).

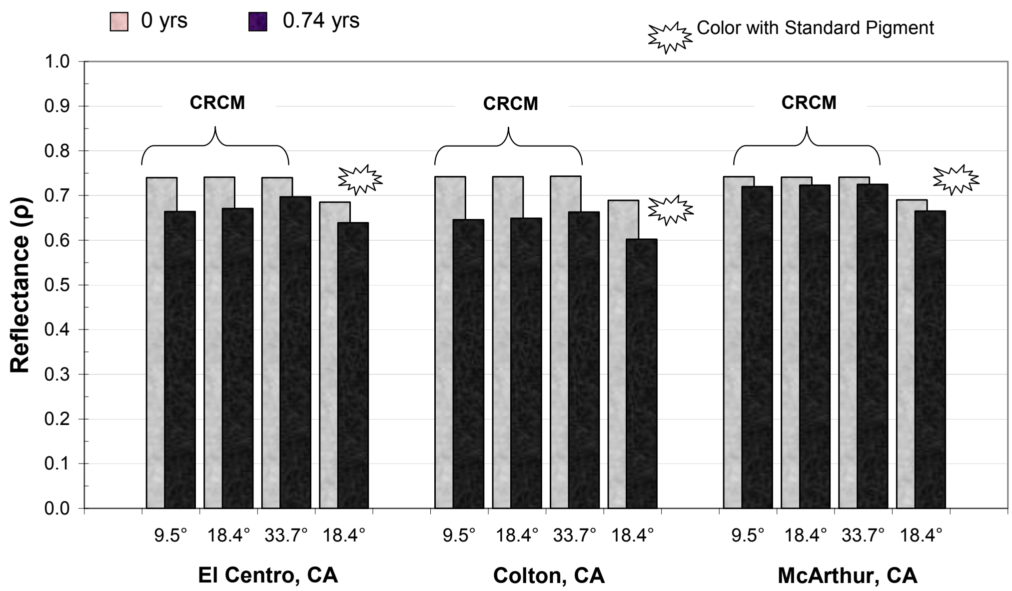

Figure 2. White painted polyvinylidene fluoride metals with and without CRCMs. The slopes of 9.5º, 18.4º and 33.7º represent respective exposure settings of 2-in, 4-in and 8-in of rise per 12-in of run.

Similar results were also observed for the clay tile samples exposed at the same weathering sites. Data for both the painted metal and the clay tile show that the roof slope does slightly affect the loss of reflectance (Fig. 2). Testing at the slope of 8-in of rise per 12-in of run (33.7º slope) has less reflectance loss as compared to testing at 2-in of rise per 12-in of run (9.5º) for all three exposure sites (Fig. 2). Exposure occurred primarily during the wetter winter months in California; however, precipitation is not believed to be the dominant player, especially when one considers that El Centro has less than 2-in of annual rainfall! Rather wind may be causing the differences in loss of reflectance as roof slope changes from 9.5º to 33.7º.

We developed a file of current weather data from the California Irrigation Management Information Systems (CIMIS) database. The current weather data for the seven CA climatic zones will be used to estimate the effects of climate on the loss of reflectance for the roof samples. We also developed a file of airborne contaminant data, which shows significant amounts of crustal elements, sulfates and total carbon around the Los Angeles and San Diego areas. Less airborne contaminants are seen in northern CA, which is consistent with our results showing cleaner samples in McArthur than those exposed near urban developments.

2.6.3 Steep-slope Assembly Testing at ORNL

Data are being acquired from the clay and concrete tile roofs being exposed on the Envelope Systems Research Apparatus (ESRA). A full week of data was acquired starting at June 25, 2004 and results of the attic air temperature are shown in Figure 3. The control is an asphalt shingle roof having a surface averaged solar reflectance of about 0.08. Initial results show the two “S”-mission tile and the low-profile tile had the lowest attic air temperatures, these being the MCA clay, the Monierlifetile concrete and the

Hanson concrete tile roofs. The Hanson tile roof has standard paint pigments and is the same concrete tile roof without cool colored pigments being tested at Cavalli Hills. The clay tile roof has the highest reflectance, 0.55, as compared to the Monierlifetile at 0.33 and Hanson at 0.08-reflectance. Surprisingly the slate tile roof on counter battens and the Eagle tile roof on battens had attic air temperatures just below the asphalt shingle control. It is expected that the air gap beneath these two tiles should support a cooler roof. Further analysis will be acquired to better understand the field trends.

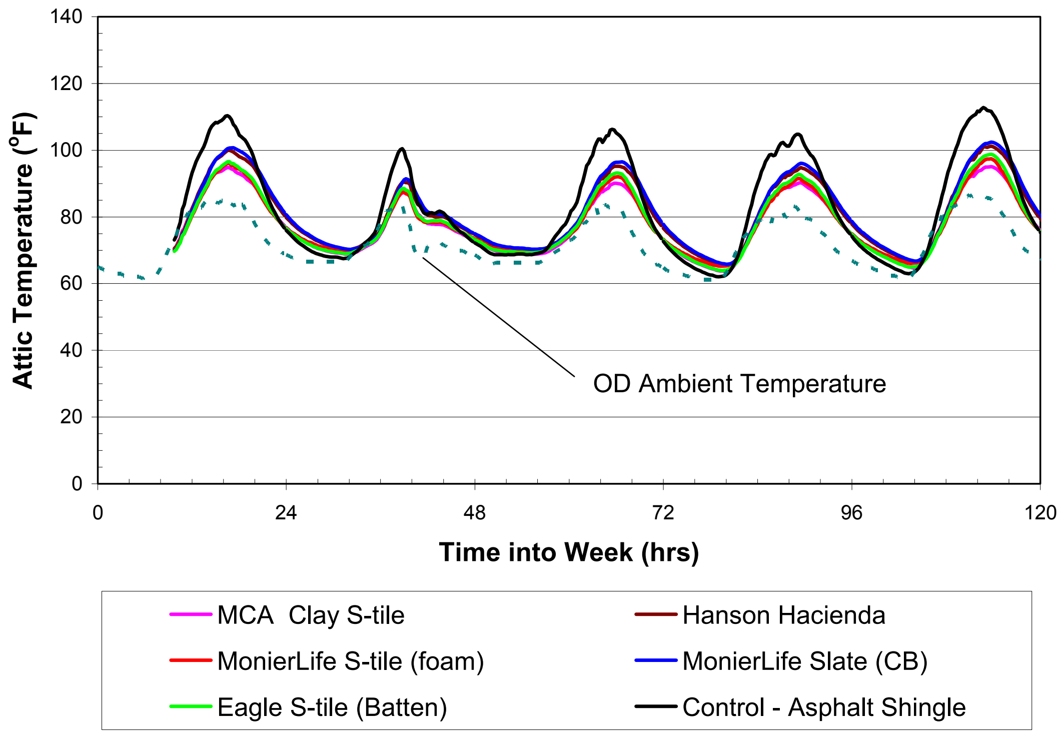

Figure 3. Attic air temperature measured under each of the tile roofs being field tested at ORNL.

2.6.4 Product Useful Life Testing

We have completed the literature survey of Task 2.5.3 above and located a few key papers providing limited data on the aging and weathering of asphalt shingles. Literature searches have shown that the degradation of asphalt, a key component in asphalt shingles, occurs because the asphalt gradually oxidizes. This oxidation makes the normally elastic and sticky material turn brittle. The oxygen for this process comes from the air, and the process is accelerated by the 300-400 nm UV in sunlight. We are planning to perform an experiment to see whether or not the oxidative degradation of asphalt shingles is accelerated by the higher temperatures experienced by less-reflective shingles. Prior work on asphalt roads has established that pavement lifetime can be shorter in hotter climates, but it does not appear to be known if the same is true for asphalt shingles. In July, we will consult with our asphalt shingle partners to refine our experimental design.

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

Project staff provided information to Mr. John Bell, who wrote an article on cool roofing that appeared in the July/August issue of *Journal of Property Management*.

Project team prepared an article titled "Cool Roof Colored Materials" for the upcoming ACEEE meeting.

We prepared an article titled "*Special IR reflective pigments make a dark roof reflect almost like a white roof*" for the upcoming THERM IX meeting. Review comments from the “Project Team” and independent reviewers were completed and the paper was submitted to ASHRAE for publication.

Levinson delivered a talk at LBNL summarizing our pigment characterization activities since 2001. The presentation is online at http://CoolColors.LBL.gov .

On April 23, Akbari and several industrial partners (Elk, MCA, Custom Bilt Metal, Certainteed, BASF, MoneirLifetile, and American Rooftile Coatings) attended the meeting of Emerging Technology Coordinating Council and presented results and cool roofing materials for demonstration. Present at the meeting were representative from California utilities (PG&E, SCE, SGE, SDGE) and Chris Scruton and Nancy Jenkins from California Energy Commission.

The project team prepared and submitted an article on "Cool Roof Colored Materials" for the ECO Structure magazine.

Akbari and Desjarlais attended the ASHRAE June meeting in Nashville, TN.

2.7.2 Market Plan

(No activity.)

2.7.3 Title 24 Code Revisions

(No activity.)

Management Issues

- Based on the comments received at the March 04, PAC meeting, we reviewed our project plans and discussed the results with the Energy Commission Project Manager.

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 06/30/2004
1	**Preliminary Activities**					
1.1	Attend Kick Off Meeting *Deliverables:* • 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 *Deliverables:* • 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 *Deliverables:* • 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 *Deliverables:* • 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 06/30/2004
2.3	PAC meetings *Deliverables:* • 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		67% (4/6)
2.4	Development of cool colored coatings					
2.4.1	Identify and Characterize Pigments with High Solar Reflectance *Deliverables:* • Pigment Characterization Data Report	6/1/02	6/1/02	12/1/04		~ 95%
2.4.2	Develop a Computer Program for Optimal Design of Cool Coatings *Deliverables:* • Computer Program	11/1/03	11/1/03	12/1/04		~ 25%
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database	6/1/03	7/1/03	6/1/05		~ 35%
2.5	Development of prototype cool-colored roofing materials					
2.5.1	Review of Roofing Materials Manufacturing Methods *Deliverables:* • Methods of Fabrication and Coloring Report	6/1/02	6/1/02	6/1/03		~ 95%
2.5.2	Design Innovative Methods for Application of Cool Coatings to Roofing Materials *Deliverables:* • Summary Coating Report • Prototype Performance Report	6/1/02	6/1/02	12/1/04		~ 75%
2.5.3	Accelerated Weathering Testing *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	6/1/05		~ 5%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 06/30/2004
2.6	Field-testing and product useful life testing					
2.6.1	Building Energy-Use Measurements at California Demonstration Sites *Deliverables:* • Demonstration Site Test Plan • Test Site Report	6/1/02	9/1/02	10/1/05		75%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05		55%
2.6.3	Steep-slope Assembly Testing at ORNL *Deliverables:* • Whole-Building Energy Model ValidationPresentation at the Pacific Coast Builders ConferenceSteep Slope Assembly Test Report	6/1/02	10/1/02	10/1/05		60%
2.6.4	Product Useful Life Testing *Deliverables:* • Solar Reflectance Test Report	5/1/04	5/1/04	6/1/05		5%
2.7	Technology transfer and market plan					
2.7.1	Technology Transfer *Deliverables:* • 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		~ 30%
2.7.2	Market Plan *Deliverables:* • Market Plan(s)	5/1/05		6/1/05		
2.7.3	Title 24 Code Revisions *Deliverables:* • 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 06/30/2004
VII	Critical Project Review(s) *Deliverables:* • Minutes of the CPR meeting					
XII (C)	Monthly Progress Reports *Deliverables:* • Monthly Progress Reports	6/1/02	6/1/02	6/1/05		64% (23/36)
XII (D)	Final Report *Deliverables:* • Final Report Outline • Final Report	3/1/05		10/1/05		
	Final Meeting *Deliverables:* • Minutes of the CPR meeting	10/15/05		10/31/05		