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

A summary of the status of Tasks and Deliverables as of July 31, 2004 is presented in Attachment 1.

HIGHLIGHTS

- The paper "*Special Infrared Reflective Pigments Make a Dark Roof Reflect Almost Like a White Roof*" was submitted to ASHRAE for final publication.
- We continue to work with tile, granule, and shingle manufacturers to develop cooler products.
- One of the industrial partners shipped us several samples of newly-designed cool shingles in late July.

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
Preparation for September PAC meeting is continuing.

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance
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

To test the model with which we intend to predict the solar spectral reflectance of paint mixtures, we prepared binary (two-component), equal-volume mixtures of 15 nonwhite cool paints. This yielded 105 unique combinations, from which we selected 32 mixtures combinations whose appearances seemed well-suited for use on roofs. (More than 32 appeared suitable, but we limited the number of candidates to match our resources). We have prepared and characterized pigmented films of these 32 1:1 volumetric mixtures. If time permits, we will also prepare and characterize 1:4 and 4:1 mixtures of these 32 combinations.

2.4.3 Develop a Database of Cool-Colored Pigments
(No activity.)

2.5 Development of Prototype Cool-Colored Roofing Materials

2.5.1 Review of Roofing Materials Manufacturing Methods
We revised the June 03 report and distributed it to our industrial partners for comments. We intend to complete and submit shortly a paper for archival publication. 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
Our activities this month focused on cool shingles and cool metal products. We used a Monte-Carlo (random-spot) technique to measure the solar reflectance of several prototype, blended cool shingle boards produced by an industrial partner. We also measured the thermal emittance of a series of cool metal roofing panels.

Ken Loyle and Bob Blonski of Ferro received a pallet of cedar shakes from Steven Harris of the Cedar Shake & Shingle Bureau. Ferro plans to paint the shakes with cool-colored pigments to make them appear weathered and still maintain Class B fire code protection.

2.5.3 Accelerated Weathering Testing
See discussion in Task 2.6.4 below.

2.6 Field-Testing and Product Useful Life Testing
Elk's marketing director John McCaskill has helped us to locate a pair of homes for demonstrating Cool Roof Color Materials (CRCMs). The homes are being built in Redding, CA and are of identical footprint. Installation of asphalt shingles with and without CRCMs can occur as early as September 13.

ORNL intern students traveled to all the weathering sites and collected reflectance and emittance measures for all the metal, clay and concrete tile samples. A few new concrete tile samples from Joe Riley were place at the Corona site.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites
ORNL personnel and Wim Boss of SMUD are installing the data acquisition system and independent phone line for the fourth demonstration house at Cavalli Hills. The fourth house is a C-style home having a painted metal roof with CRCMs. Solar reflectance of the painted metal is 0.31. Power instrumentation is also being checked because field measurements appear too low for each of the three demonstration homes that are online.

After the negotiations failed with Daues of Mercy Housing, Elk's marketing director John McCaskill and Lou Hahn worked through their marketing contacts and located a residential site in Redding CA for demonstrating asphalt shingles with and without CRCMs. The contractor is building several new homes and a pair adjacent one another are available for demonstrating CRCM roofs. The footprint of the two homes is identical; it being about 1600 square feet.

Demonstration of cedar shakes cannot occur until the CRCM paints are proven to not detrimentally affect the fire retardants in the cedar shake.

2.6.2 Materials Testing at Weathering Farms in California

ORNL personnel visited the exposure sites in late July, made reflectance and emittance measurements and installed additional concrete tile samples prepared by American Roof Tile Coatings. On their previous visit in May, ORNL personnel were unable to complete work at the Steelscape weathering site in Richmond, CA and requested support from Akbari and Levinson of LBNL, who retrieved the samples and made solar reflectance, solar spectral reflectance, and thermal emittance measurements of the samples. ORNL personnel then reinstalled the samples back in Richmond, CA.

The painted metal samples continue to collect dust with the worst soiling still occurring for samples exposed in Colton. BASF provided all the painted metals, and each weathering site has three samples with CRCMs plus a single sample with standard color pigments. For example, the white painted polyvinylidene fluoride samples with standard pigments had a starting solar reflectance of 0.70, while BASF's "Ultra Cool" sample had a solar reflectance of 0.75. The brick red samples with CRCMs had a starting solar reflectance of 0.38; brick red with standard pigments had a solar reflectance of 0.18. Exposure results for the white painted metals and the brick red painted metals are shown in Figures 1 and 2.

The crisp and clear alpine climate of McArthur continues to show the lowest loss of reflectance (Fig. 1). The additional July, 04 data shows that the roof slope does affect the loss of reflectance (Fig. 1) for the white painted metals; however the darker colors show less of an effect (Fig. 2). Testing of white painted metals 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. 1). Once again, wind may be causing the differences in loss of reflectance as roof slope changes from 9.5º to 33.7º. Another very interesting trend emerging from the field exposures is the similarity of reflectance after one year for the white painted metal Ultra Cool samples and the standard color samples from BASF. Testing at the slope of 4-in of rise per 12-in of run (18.4º slope) is showing the reflectance to be converging to about the same value for the white painted metal samples (Fig. 1) for testing in El Centro and Colton. As the samples become more soiled, the benefit of the Ultra Cool's higher reflectance appears to be diminishing as compared to the same white color sample with standard pigments.

The trends however for darker color CRCM samples are not as consistent as those for the white painted metal samples. In fact, reflectance increased slightly for all exposure slopes in El Centro for the brick red painted metal samples (Fig. 2). In Colton, there is observed a loss of reflectance with exception of the samples with standard pigments. In the alpine climate of McArthur, it appears the samples lost reflectance and then regained reflectance possibly due to washing by rainfall. The results are somewhat confounding, yet all the darker color metal samples are showing similar trends as shown in Figure 2 for the brick red color. For Colton and El Centro, the standard pigmented red brick color increased reflectance from 0.195 to 0.250, a 0.055 increase, which is near the threshold accuracy for the Device & Services reflectometer. Previous comparisons of the ORNL and LBNL reflectometer against the LBNL spectrometer showed measurements for a sample of

BASF painted metals within an average accuracy of about 0.02 reflectance points. Variation in airborne particulate matter between the different sites can also be affecting the trends for the change in reflectance.

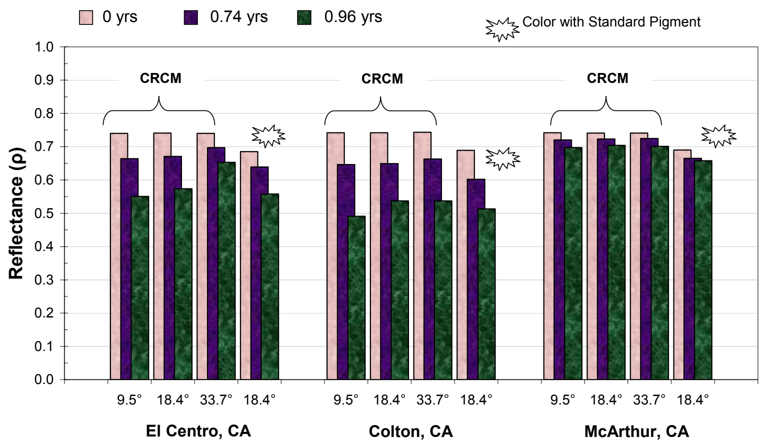

Figure 1. White painted polyvinylidene fluoride metals with and without CRCMs. The slopes of 9.5°, 18.4° and 33.7° represent respective exposure settings of 2-in, 4-in and 8-in of rise per 12-in of run.

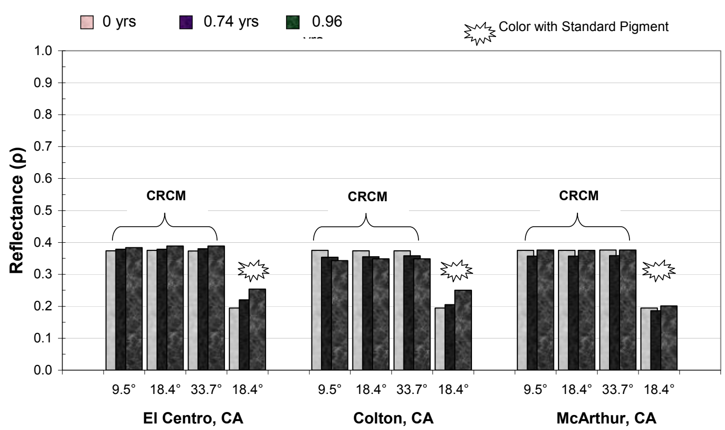

Figure 2. Red brick painted polyvinylidene fluoride metals with and without CRCMs. The slopes of 9.5°, 18.4° and 33.7° represent respective exposure settings of 2-in, 4-in and 8-in of rise per 12-in of run.

2.6.3 Steep-slope Assembly Testing at ORNL

The results of attic air temperatures for the tile roofs under test at ORNL were studied for any confounding variables. It was found that the fourth lane having slate tile on a counter-batten construction had its attic cavity sealed thereby allowing no soffit-to-ridge ventilation within the attic as occurring in the other five test roof assemblies. The fourth lane's soffit vent was sealed from a previous experimental design. The problem is corrected and further data will be shown next period to compare all roofs with nearly the same attic ventilation.

2.6.4 Product Useful Life Testing

The design of an experiment to find out if cooler asphalt shingles will last longer continued with discussions with industrial partners. More work on this topic is needed, and will continue in August.

One reason this is a difficult topic is that there is no industry consensus on how to measure asphalt shingle degradation and lifetime. A typical failure mechanism is that the shingles begin to crack under stress. In many cases the stress due to wind is a factor. The cracking is associated with the gradual hardening and increased brittleness over time. The brittleness is associated both with oxidation of the asphalt and with the out-diffusion of low molecular weight (plasticizer-like) components. Another failure mechanism is the loss of the granule surfacing, followed by rapid UV degradation.

Our initial plan was to evaluate shingle degradation using the 3M industry standard abrasion test (granule loss due to steel brush abrasion). However, other tests of mechanical properties, particularly bending stiffness, may be more appropriate. One test involves cooling the shingle to about 30ºF and measuring the force and displacement as it is bent to failure. Another option would be non-destructive measurement of stiffness.

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

The paper "*Special Infrared Reflective Pigments Make a Dark Roof Reflect Almost Like a White Roof*" was submitted to ASHRAE for final 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 07/31/2004
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 07/31/2004
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		~ 97%
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		~ 30%
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database	6/1/03	7/1/03	6/1/05		~ 40%
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		~ 97%
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		~ 80%
2.5.3	Accelerated Weathering Testing *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	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 07/31/2004
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		77%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05		60%
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		10%
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		~ 35%
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 07/31/2004
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		67% (24/36)
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		