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To: Chris Scruton (CEC)
From: Steve Wiel
Subject: **Cool Roof Colored Materials**: Monthly Progress Report for April 2005
CC: Hashem Akbari, Paul Berdahl, Andre Desjarlais, Nancy Jenkins, Bill Miller, Ronnen Levinson

A summary of the status of Tasks and Deliverables as of April 30, 2005 is presented in Attachment 1.

HIGHLIGHTS

- We created a beta version of "Pinwheel," our coating formulation software, and shared it with our program manager at CEC.
- We are working to complete the deliverables for Tasks 2.5.2, 2.6.4, 2.7.2, and 2.7.3 by the end of May 2005.
- Concrete and clay tile roofs are becoming more and more appealing as the combination of cool roof color materials, venting the underside of the tile and thermal mass are showing upwards of 70% drop in the heat penetrating the roof during the summer while both mass and venting partially reduce the heating penalty associated with a cool roof.

Tasks

1.1 Attend Kick-Off Meeting
Task completed.

1.2 Describe Synergistic Projects
Task completed.

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

2.2 Software Standardization
(No activity.)

2.3 PAC Meetings
Task completed.

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance
Task completed.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings
We have created a beta version of "Pinwheel," our coating formulation software, and shared it with our program manager at CEC. The beta version of the Pinwheel will be released to our industrial partners in May pending a licensing review required by LBNL patent office.

The software has been calibrated by comparing its predictions to the known compositions, visible spectral reflectances, and solar reflectance of mixtures prepared and characterized earlier in this project. We improved its performance by using absorption coefficients derived from the characterizations of tints (mixtures with white) in place of those obtained from the characterizations of masstones. The obsolete process tends to underestimate absorption by strongly absorbing pigments, and consequently overpredict the reflectance of mixtures containing such pigments.

2.4.3 Develop a Database of Cool-Colored Pigments
Task completed.

2.5 Development of Prototype Cool-Colored Roofing Materials

2.5.1 Review of Roofing Materials Manufacturing Methods
Task completed.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials
A brief report summarizing all the activities and accomplishments under this task is being prepared. We are planning to complete this report in May 2005.

2.5.3 Accelerated Weathering Testing
Ben Simkin of Arkema, Inc. provided us with materials on the weathering of PVDF roof coatings. Work on the manuscript on accelerated weathering is awaiting the completion of the manuscript of task 2.6.4. We expect to complete this report by the end of June 2005.

2.6 Field-Testing and Product Useful Life Testing
The Memorandum of Understanding (MOU) for the asphalt shingle field demonstrations has been signed by Elk Corp., ORNL and by Ochoa and Shehan Inc. A copy is being sent to all participants involved with the Redding CA demonstrations

Field data for the steep-slope attic assemblies at ORNL show that the tile with cool roof colored materials (CRCMs) drops the ceiling heat flux by 70% of the flux measured for the adjacent shingle roof. Further the thermal mass of the tile nearly counter balances the winter time heating penalty in the moderate climate of Tennessee.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites
Asphalt Shingle Demonstrations: A Memorandum of Understanding (MOU) has been approved by Elk's Product Brand Manager, John McCaskil, and by Jerry Wagar of Ochoa and Shehan Inc and also by ORNL. Final copies of the document are being forwarded to all parties

Painted Metal and Concrete Demonstrations: W. Miller made a second contact with the residents in Fair Oaks, CA who agreed to participate in the cool metal and cool concrete roof demonstrations. The residents will air-condition their homes during the months May

through September 05. In exchange ORNL will reimburse their electric bill from funds provided ORNL by LBNL and the CEC.

2.6.2 Materials Testing at Weathering Farms in California

ORNL's Environmental Science Division (ESD) is in process of measuring the elemental composition of the dust collected from the roof samples exposed at the seven CA weathering sites.

A subcontract was approved by ORNL purchasing for acquiring the services of the Biomarker Analysis Center at the University of Tennessee. The contract is awaiting approval by UT. Dr. Susan Pfiffner will analyze samples from the weathering sites to determine whether a microbial community exists on the samples exposed in California.

2.6.3 Steep-slope Assembly Testing at ORNL

Field data for the tile roof assemblies were reduced for the months of August 04 and January 05 to view the total flux crossing the roof deck and ceiling of each attic assembly. Table 1 lists the reduced data for the day time hours in August 04 for the S-mission clay tile (SR54E90), the concrete slate tile (SR13E83) and the asphalt shingle (SR10E89) roofs. The S-mission clay tile and asphalt shingle are direct nailed to the deck while the slate is installed on counter battens. The addition of cool colored pigments to the clay tile has dropped the heat penetrating the roof deck by 72% of that measured for the asphalt shingle roof. The reduction is due in part to the cool pigments but is also due to the venting occurring along the underside of the tile roof. It is very interesting that the dark slate tile (SR13E83) as compared to the shingle roof (SR10E89) reduced the deck heat flow by 40%, which clearly shows the benefit derived from venting the roof deck. Proportioning the percentage drops based on the integrated day time loads (i.e., ~40% reduction for the SR13E83 and a 72% drop for the SR54E90 tile as compared to the shingle roof), to the difference in solar reflectance for the clay tile (SR54E90) and the asphalt shingle (SR10E90) yields about 25 points of solar reflectance.

Table 1. Thermal performance of tile roofs measured during August 04 daylight hours.

Roof	Roof Deck	Surface (^{o}F)		Attic Air (^{o}F)		Heat Flux (Btu/ft^2)	
		Average	Max	Average	Max	Ceiling	Deck
S-mission	Direct-to-Deck	91.0	135.7	79.7	99.0	242.3	1127.4
Slate	Counter Batten	100.1	154.6	81.8	106.2	466.3	2446.2
Shingle	Direct-to-Deck	101.3	162.5	86.3	115.7	1047.6	4099.4

$$\overbrace{\frac{40\%\ \text{due to venting}}{72\%\ \text{due to venting and SR}}}^{\text{heat reduction}} \cdot \left[SR54_{\text{Clay Tile}} - SR10_{\text{Shingle}} \right]$$

Therefore venting may very well credit the dark slate tile with an addition 25 points of solar reflectance. It is difficult to judge whether venting or surface reflectance is the predominant force dropping the roof flux. However, Beal and Chandra (1995) showed

that S-mission tile on battens reduced the heat penetrating the ceiling an additional 11% as compared to the same tile of the same color direct-nailed to the deck.

Data for the month of January 05 show that the thermal mass of the tile roofs nearly counter balances the heating penalty associated with cool roofing for the moderate climate of TN. Again venting the underside of the tile plays a part in the results (Fig. 1).

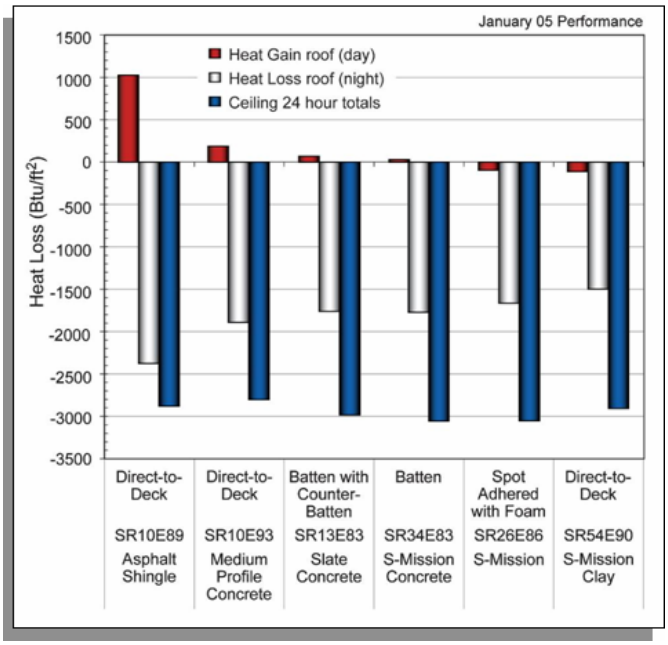

Figure 1. Heat flow measured for all tile and shingle roofs during the month of January. 05.

The asphalt shingle roof gains about 1000 Btu per square foot of roof deck during all January days while the tile roofs show little gain and some a loss of heat from the roof deck. However, during the evening hours the thermal mass and possibly the tile's air gap have reduced the heat loss from the roof to the point that the heat loss from the ceiling of all roofs is about the same (see blue bars Fig. 1). These data are very promising because the tile roofs are negating the heating penalty associated with a cool roof in TN's moderate climate having 3662 HDD_{65} and 1366 CDD_{65}.

Beal, D., and S. Chandra. 1995. "The measured summer performance of tile roof systems and attic ventilation strategies in hot, humid climates." in Thermal Performance of the Exterior Envelopes of Buildings, VI. Atlanta: American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

2.6.4 Product Useful Life Testing

Having earlier completed an outline and bibliography for our review article on weathering of roofing, we are currently writing the article. The article lists the various physical, chemical, and biological stresses on roofing materials and discusses how manufacturers tailor their manufacturing processes to manage these stresses. We are planning to complete the article in May.

The Shepherd Color Company and 3M Mineral have received all roof samples planned for accelerated testing. Both companies will start testing in May. Shepherd will test with accelerated fluorescent light exposure while 3M Mineral will test with Xenon-arc exposure. The accelerated exposure testing will include samples with and without cool-pigmented colors. The materials being tested are painted metal samples, clay tile samples, concrete tiles with American Rooftile coating and four cool prototype shingles. The painted metal, clay tile and concrete tile with coatings are already under natural exposure testing at the seven California weathering sites. A second shingle manufacturer has agreed to provide both fluorescent and Xenon-arc test data. However, he preferred to not provide prototype shingles for testing at Shepherd or 3M Mineral. He would rather his company conduct the testing. Therefore, to foster cooperation while protecting product identity, the four shingles being tested at Shepherd and 3M Mineral have been assigned codes. The data from the second shingle manufacturer will also be similarly coded.

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

The National Coil Coaters Association (NCCA) invited W. Miller to give presentation at their annual conference held May 7 – 9 in Ft. Myers, FL. NCCA's theme for the conference is "Success through Association." Miller therefore will present results of the painted metals being demonstrated in CA and will emphasize the collaboration among industry participants working with LBNL and ORNL on the cool pigment study for the CEC. Presentations were also prepared for the upcoming RCI conference "Cutting through the Glare" scheduled for May 11- 13, 05.

On April 20, 2005, Akbari gave a lecture on cool colored roofing materials at the San Francisco State University.

2.7.2 Market Plan

The work for development of a market plan for implementation of cool colored roofing material was started on April 1, 2005. We prepared an extended outline. ORNL and LBNL are working to complete the document in May 2005.

2.7.3 Title 24 Code Revisions

Akbari continues working with PG&E and the Energy Commission to develop a plan for code change proposal for sloped-roof residential buildings. We have developed a preliminary estimates of savings obtained from the installation of cool colored roofs on air conditioned houses in all California climate regions. A short report summarizing these data will be prepared in May 2005.

Management Issues

None.

Attachment 1

Project Tasks and Schedules (*Approved on May 16, 2002; Revised schedules approved November 2004*)

Task	Task Title and Deliverables	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 4/30/2005
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**) • Finalize Initial PAC Organization Membership List (**Completed**) • PAC Meeting Schedule (**Completed)** • Letters of Acceptance (**Completed)**	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 4/30/2005
2.3	PAC meetings (**Completed)** *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		100% (6/6)
2.4	Development of cool colored coatings					
2.4.1	Identify and Characterize Pigments with High Solar Reflectance *Deliverables:* • Pigment Characterization Data Report (**Completed)**	6/1/02	6/1/02	12/1/04 → 12/31/04		100%
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 → 5/1/05		~ 98%
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database (**Completed)**	6/1/03	7/1/03	6/1/05 → 12/31/04		100%
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 (**Completed)**	6/1/02	6/1/02	6/1/03		100%
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 → 5/1/05		~ 99%
2.5.3	Accelerated Weathering Testing *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	6/1/05 → 10/1/05		~ 60%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 4/30/2005
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 (**Completed)** • Test Site Report	6/1/02	9/1/02	10/1/05 → 10/1/06		88%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05 → 10/1/06		79%
2.6.3	Steep-slope Assembly Testing at ORNL *Deliverables:* • 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		85%
2.6.4	Product Useful Life Testing *Deliverables:* • Solar Reflectance Test Report	5/1/04	5/1/04	6/1/05 → 10/1/05		65%
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		~ 98%
2.7.2	Market Plan *Deliverables:* • Market Plan(s)	5/1/05	4/1/05	6/1/05		50%
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		~ 85%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 4/30/2005
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		97% (35/36)
XII (D)	Final Report *Deliverables:* • Final Report Outline • Final Report	3/1/05 → 3/31/06		10/1/05 → 10/1/06		
	Final Meeting *Deliverables:* • Minutes of the final meeting	10/15/05		10/31/05		