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January 12, 2004

To: Chris Scruton (CEC)
From: Steve Wiel
Subject: **Cool Roof Colored Materials**: Monthly Progress Report for December 2003
CC: Hashem Akbari, Paul Berdahl, Andre Desjarlais, Bill Miller, Ronnen Levinson

A summary of the status of Tasks and Deliverables as of December 31, 2003 is presented in Attachment 1.

HIGHLIGHTS

- We have completed the preparation and optical measurements of tints (mixtures with white) of all pigments, and are using this data to develop a model predicting the performance of mixtures.
- We continue to work with tile, granule, and shingle manufacturers to develop cooler products, focusing this month on (a) cool glazes for clay tiles, (b) cool acrylic coatings for concrete tiles, and (c) coatings for granules.
- We are negotiating a second demonstration site with Four Seasons Construction Co. in Sacramento for testing asphalt shingles with and without colored cool materials.

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
(No activity.)

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance
We have completed the preparation and optical measurements of tints (mixtures with white) of all pigments, and are using this data to develop a model predicting the performance of mixtures. We continue to revise our pigment characterization draft paper, and expect to finalize the paper in January.

We compared our measurements for the scattering strength S of conventional white titanium dioxide pigment with theoretical estimates from the published literature. Theory gives S-values of about 11±1 per micrometer (times the pigment volume concentration), for the center of the visible spectrum at 550 nm. These theoretical estimates are based on the Mie theory for light scattering from spherical particles, together with a simple model of multiple scattering effects in white coatings. We find good order-of-magnitude agreement with our measurements, which is in contrast with many of the older studies of this issue.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings
(No activity.)

2.4.3 Develop a Database of Cool-Colored Pigments
We forwarded data to our partners and responded to partners' questions and comments.

2.5 Development of Prototype Cool-Colored Roofing Materials

2.5.1 Review of Roofing Materials Manufacturing Methods
We are still working to arrange a visit to a cedar shake roof-manufacturing plant.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials
We continue to work with tile, granule, and shingle manufacturers to develop cooler products, focusing this month on (a) cool glazes for clay tiles, (b) cool acrylic coatings for concrete tiles, and (c) coatings for granules.

We have taken the first step in characterizing glazes by measuring the solar spectral reflectances of a series of white tiles coated with glazes containing increasing concentrations of pigments (e.g., 0.5%, 1%, 2%, 4%, and 6%) for about 20 Ferro ceramic colors. We will use these "concentration ladders" to determine the scattering and absorption coefficients of the glazes.

We suggested some modifications to prototypical coatings for granules and concrete tiles that had been developed and tested earlier in this project; these modified coatings are being prepared by our industrial partners. We are also in the process of measuring the solar reflectance of some heterogeneously coated asphalt shingles received from an industrial partner. We are using a Monte-Carlo technique to determine the reflectance of these non-uniform shingles. That is, we measure the reflectance of each shingle at many locations until the average reflectance changes very slowly with each additional measurement.

2.5.3 Accelerated Weathering Testing
(No activity.)

2.6 Field-Testing and Product Useful Life Testing
A second demonstration site is being negotiated for testing asphalt shingles with and without cool colored roofing materials. A Memorandum of Understanding was forwarded to the Four Seasons Construction Co. for review to possibly work with ORNL and

SMUD in demonstrating cool asphalt shingles. A 40 house subdivision in the suburbs of Sacramento has several lots available for conducting side-by-side field testing.

Steve Berlin of CNS Publishing is publishing in the Weekly Bulletin of the Sacramento Building Exchange highlights of the CEC PIER project for demonstrating cool colored roofing materials. Burlin's news clip is attached in the Appendix.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites

Rinkydink Builders installed painted aluminum shakes on one of two C style houses being field tested in Cavalli Hills. Mike Cercel of Rinkydink taped thermocouple wires, seen protruding from each roof (Fig. 1), to the underside on a shake for measuring the surface temperature of the roof. The metal shake is very thin and therefore the thermocouple will yield an accurate measure of the roof temperature. The color of the aluminum shake is walnut brown and it contains no cool colored pigments. Solar reflectance of the walnut brown is about 0.08. The aluminum shingles for the second C style house will have Custom-Bilt Metals "musket brown" color and have cool colored pigments. Solar reflectance of the musket brown is about 0.31, almost a factor of 4 greater that the standard walnut brown. The second C style home is under construction, and ORNL personnel are scheduled to visit Cavalli Hills the third week in February to complete setup of the data acquisition system for the first three homes and to run wiring for the second C style house.

Figure 1. Thermocouple used for measuring metal roof temperature.

Inclement weather has prevented Joe Riley of American Roof Tile Coatings from applying the topcoat finish with cool pigments to one of the two installed tile roofs. Riley is scheduled to complete the work in February while ORNL personnel are at the demonstration site. The cool pigments topcoat will boost the reflectance of the dark brown tile from about 25% to almost 45%.

2.6.2 Materials Testing at Weathering Farms in California
No activity this period.

2.6.3 Steep-slope Assembly Testing at ORNL
No activity this period.

2.6.4 Product Useful Life Testing
(No activity.)

2.7 Technology transfer and market plan

2.7.1 Technology Transfer
Akbari gave two presentations on colored cool roofs and heat-island technologies in a building-energy-efficiency workshop in Kuwait.

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 12/31/2003
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 12/31/2003
2.3	PAC meetings *Deliverables:* • Draft PAC meeting agenda(s) with back-up materials for agenda itemsFinal PAC meeting agenda(s) with back-up materials for agenda items Schedule of Critical Project ReviewsDraft PAC Meeting Summaries • Final PAC Meeting Summaries	9/1/02	6/1/02	6/1/05		50% (3/6)
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		~ 70%
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		< 2%
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database	6/1/03	7/1/03	6/1/05		~ 10%
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		~ 30%
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 12/31/2003
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		35%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05		35%
2.6.3	Steep-slope Assembly Testing at ORNL *Deliverables:* • Whole-Building Energy Model Validation Presentation at the Pacific Coast Builders ConferenceSteep Slope Assembly Test Report	6/1/02	10/1/02	10/1/05		25%
2.6.4	Product Useful Life Testing *Deliverables:* • Solar Reflectance Test Report	5/1/04		6/1/05		
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		~ 5%
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		~ 5%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 12/31/2003
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		53% (19/36)
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		

Appendix

Weekly Bulletin
Sacramento Building Exchange
By Steve Berlin

If you have ever left a metal hammer lying out in the summer sun, you know that when you go to pick it up it is hot. Even though the hammer is shiny and therefore reflects the sunlight, the metal retains the heat over time, giving it up slowly.

According to Chris Scruton of the California Energy Commission, the term for this is emissivity. Shiny metal, Chris notes, has a low emittance and does not give off heat energy easily.

The basic concept of a cool roof is to make the roof out of a material that reflects energy and also emits heat -- not retaining it like the hammer left in the sunshine.

Presently, suitable cool *white* materials are available for most roof products, with the notable exception of asphalt shingles; cooler *colored* materials are needed for all types of roofing. The home market has virtually refused to use cool roof materials solely because they are white in color.

It is the hope and intent of the current Energy Commission research project to develop materials that work as well, or better, than existing materials and come in colors acceptable to both commercial and residential builders.

The California Energy Commission is engaging Lawrence Berkeley National Laboratory (LBNL) and Oak Ridge National Laboratory (ORNL) to work on a three-year, $2 million project with the roofing industry to develop and produce reflective, colored roofing products and with the homebuilding industry to test these products.

Last weeks feature story on Insulated Concrete Form Construction (Weekly Bulletin Jan. 8, 2004) noted that progressive homebuilder Mike Evans is working with the Sacramento Municipal Utility District to collect thermal performance data for a new generation of cool roof materials.

Homeowners have already agreed to have passive thermal monitoring systems installed in the attics and around the house. Data will be collected from housing having only a cool roof, from housing having a cool roof and the insulated concrete form construction walls, and also from standard wood framed homes. Comparison of the data will yield useful information on the energy savings and thermal properties of both the ICF wall system and the new generation of cool roofs.

Most painted roofs today have a reflectance of about 10 - 20 percent, but special paint made using cool roof color materials can reflect as much as 60 percent of the sun s energy, cutting air conditioning bills by 20 percent or more.

Steve Weil of the Lawrence Berkeley National Lab, who is project manager for the Cool Roof testing program being funded by the California Energy Commission, explains that they are testing a new generation of Cool Roof paints, coatings and materials. The expectations are threefold.

First, the new coatings and materials are expected to dramatically lower the surface temperatures of the roof in summer, which will increase the lifetime of the roof.

Second, the lower surface temperature will mean less heat transfer into the house, and lower air conditioning costs and lower energy usage.

Finally, the new materials will reduce the ambient air temperature in the locale of the building because the Cool Roof materials actually reflect energy into space.

If Cool Roofs are adopted widely, this aspect of reflecting energy back into space will have a significant and positive effect on the growing problem of urban heat islands.

Chris Scruton of the Energy Commission also noted that the high reflectivity of the Cool Roof will have air quality benefits. Smog, says Scruton, forms more quickly when the air temperature is higher. That

is why smog is not as big a problem in the winter. If an entire community had Cool Roofs that reflected solar energy back into space, it would have a mitigating effect on smog formation.

Until recently the major drawback of a Cool Roof was that they came in only one color: white.

The new generation of Cool Roof materials and paints come in a variety of colors and perform better.

The intended outcome of this project is to make cool-colored roofing materials a market reality within three to five years. For other materials, the aim is a reflectance of over 45 percent.

"Raising roof reflectivity from an existing 10-20 percent to about 60 percent can reduce cooling-energy use in buildings in excess of 20 percent," states Hashem Akbari of LBNL. Cool roofs also result in a lower ambient temperature that further decreases the need for air conditioning and retards smog formation. Those reflective roofing products currently available in the market e.g., single-ply membranes and spray-on roof coatings are typically used for low-sloped roofs (mostly commercial buildings) and not for homes with steep-sloped roofs.

LBNL and ORNL are working with pigment manufacturers and roofing materials manufacturers to develop Cool Roof materials that reduce the sunlit temperatures of colored asphalt shingles, roofing tiles, metal roofing, wood shakes, roofing membranes and roof coatings. A significant portion of the effort will be devoted to materials design to continue to improve pigments for cool-colored materials, and to the development of engineering methods for applying colored pigment on roofing materials. The project will also measure and document the laboratory and on-site performance of roofing products.