ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Hashem Akbari, Project Director
Heat Island Group
Environmental Energy Technologies Division

MS 90R4000
1 Cyclotron Road
Berkeley, CA 94720

Tel. 510-486-4287
Fax: 510-486-6996
e-mail: H_Akbari@lbl.gov

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

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

## HIGHLIGHTS

- The market plan was finalized. The plan was reviewed by several PAC members and all were in full agreement to implement the actions described in the report. The report outlines six market interventions available to the CEC to reduce or eliminate barriers that slow the market penetration of cool roofing products into the residential housing market. The market initiatives are: 1) regulate, 2) increase product selection, 3) label, 4) educate, 5) provide incentives, and 6) demonstrate performance. **Task 2.7.2 is now completed**.
- The rough draft of our review article on weathering was essentially completed by Berdahl in July. It is entitled, "Weathering of Roofing Materials-An Overview." It features photo-oxidation, effects of elevated temperatures, effects of moisture, and soiling of roofing materials. We are in the process of reviewing and finalizing the paper.
- The completion date for the deliverable of Task 2.6.4 has been postponed to the end of August 2005.

## 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
**Task completed**.

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
**Task completed**.

2.5.3 Accelerated Weathering Testing
No activity during July 2005. Work on the manuscript on accelerated weathering is awaiting the completion of the manuscript of Task 2.6.4.

2.6 Field-Testing and Product Useful Life Testing
Measures of the airflow underneath the clay and concrete tile roofs being tested at ORNL were made using tracer gas techniques. Data compared reasonably well to classic boundary layer theory and to data reductions using the temperature and heat flow data acquired from each steep-slope attic assembly to calculate the airflow rate under the tile.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites
*Asphalt Shingle Demonstrations*: July ambient air temperatures at solar noon exceeded 110°F (45°C) in Redding, CA. Data for this hot period shows the heat flux penetrating the west-facing cool-pigmented roof to be 28% less than the conventional color roof. Attic air temperatures show the attic for the roof with cool pigments as being about 7°F (4K) cooler at solar noon.

*Painted Metal and Concrete Demonstrations*: The pair of homes demonstrating painted metal shakes with and without cool pigments show from May 13 until present about a 25% reduction in the whole house power for the house roofed with cool pigmented colors.

2.6.2 Materials Testing at Weathering Farms in California
Dr. Susan Pfiffner continues working on the biomass analysis of similar samples. Samples are being fractionated for determining lipid content from which biomass is evaluated as either fungal or bacterial mass. Samples continue to be exposed in the seven weathering sites in California.

2.6.3 Steep-slope Assembly Testing at ORNL
Measurements were made of the airflow occurring underneath the clay and concrete tile roofs as the buoyancy-driven airflow moved from the soffit to the ridge of each roof. The

goal is to predict that portion of heat transfer that penetrates the tile and is swept by thermal buoyancy toward the ridge vent. The calculation requires an accurate prediction of the airflow rate under the enclosed vent cavity of the tile. We designed a procedure using tracer gas techniques outlined in ASTM E 741 and also by Lagus et al. (1988). The procedure requires monitoring the decay rate of the tracer gas $CO_2$ with time. Three $CO_2$ monitors were placed inside each attic space and sampling tubes were inserted into the vent cavity from the underside of the oriented strand board (OSB) decking. The monitors sampled the gas concentration near the soffit, at the center of the roof and within two-feet of the ridge vent. We injected the gas into the vent gap at the soffit at a relatively high rate to saturate the cavity with $CO_2$ gas. After a substantial buildup of concentration registered on each monitor (i.e., 20,000 PPMV of $CO_2$) the gas injection was stopped and $CO_2$ concentration was recorded at timed intervals (Fig. 1). Data for the five vented clay and concrete tile roofs were collected (Table 1) and the calculated airflows ranged from about 12 to 40 cfm (0.005 to 0.02 $m^3$/sec). The average velocity ranged from about 0.4 to 0.9 ft/s (0.12 to 0.27 m/s), which is consistent with velocity calculated from boundary layer theory.

Table 1. Airflow rate and bulk velocity measured under the clay and concrete tile roofs using tracer gas techniques.

| | | S-Mission | Medium Profile | S-Mission with foam | Slate on Counter Batten | S_Mission on Batten |
|---|---|---|---|---|---|---|
| | | Clay | Concrete Tile | | | |
| | Volume ($in^3$) | 7910.9 | 5831.7 | 5531.5 | 5433.1 | 6914.4 |
| | Airflow (cfm) | 36.8 | 12.5 | 17.6 | 19.3 | 23.3 |
| Average Velocity (ft/s) | | 0.879 | 0.405 | 0.600 | 0.672 | 0.636 |

All data were collected at solar noon when the roofs had their highest respective roof temperatures and heat flows penetrating into the attic. The clay tile yielded the highest measured buoyancy induced airflow, which is very interesting because the combination of its solar reflectance and airflow underneath the S-mission tile are believed the drivers causing the 72% reduction in deck heat flow as compared to a direct nailed shingle roof.

Energy balances for internal duct flow were derived using constant wall and constant heat flux boundary conditions and the airflow in the enclosed cavity was calculated using the measured temperature and heat flow data for the five tile roof systems. Using a constant temperature boundary condition yields the expression:

$$LN\left[\frac{T_{Wall} - T_{Air\,out}}{T_{Wall} - T_{Air\,in}}\right] = -\frac{\hbar\{P \cdot L\}}{\dot{m}(C_{P\,Air})}$$

while the constant flux condition yields the expression:

$$\dot{m} \cdot C_{P\,Air}\left(T_{Air\,out} - T_{Air\,in}\right) = q''_{solar}(P \cdot L)$$

where

T represents field temperature data

P perimeter of the duct
L length of the duct

The constant surface temperature scenario gave mass flow rate calculations of about 0.03 to 0.04 lbm/s. The constant heat flux condition yielded mass flow rates around 0.05 to 0.10 lbm/s, which is high probably because we used the measured solar irradiance rather than the flux from the underside of the tile (not easily known from field data). The corresponding airflow values range from 24 to a high of 80 cfm, and are within reason of the airflows determined from the tracer gas experiments (Table 1).

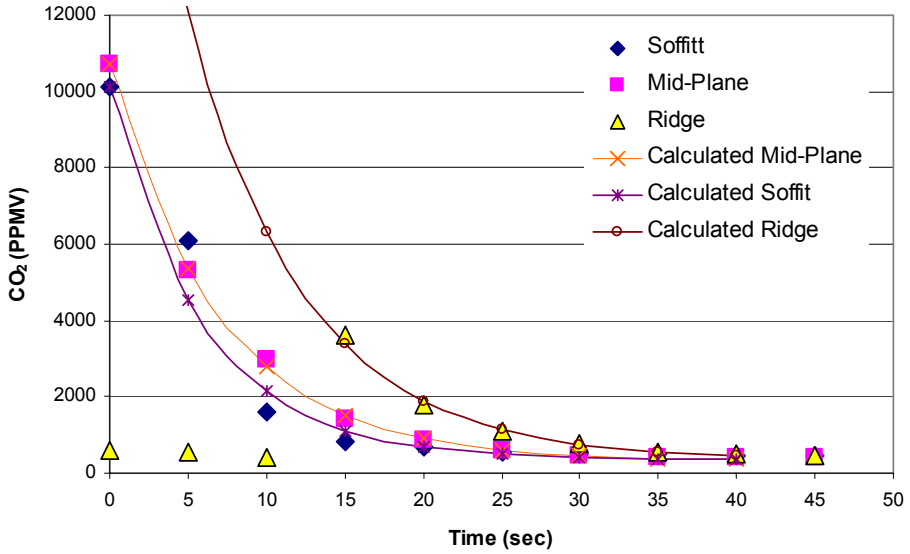


Figure 1. Concentration of $CO_2$ measured in the slate tile roof on batten and counter battens.

2.6.4 Product Useful Life Testing

The rough draft of our review article on weathering was essentially completed by Berdahl in July. It is entitled, "Weathering of Roofing Materials-An Overview." It features photo-oxidation, effects of elevated temperatures, effects of moisture, and soiling of roofing materials. We are in the process of reviewing and finalizing the paper.

The Shepherd Color Company and 3M Mineral continue to subject roof samples with and without cool colored coatings to accelerated fluorescent and Xenon-arc exposures. Shepherd has logged about 2000 hours of exposure. 3M has completed 1000 hours of Xenon-arc exposure, and some preliminary data for the asphalt shingles is given after 1000 hours of Xenon-Arc exposure (Table 2).

Table 2. Total Color Change for some of the asphalt shingles subjected to 1000 hours of Xenon-Arc exposure.

| Pigments | CRCM | Standard | CRCM | Standard | CRCM | Standard |
|---|---|---|---|---|---|---|
| Asphalt Shingles | A1[1] | B1 | C2[2] | D2 | E1 | F1 |
| Total Color Change ΔE | 0.55 | 1.66 | 1.26 | 0.93 | 0.45 | 0.22 |

[1,2] Index 1 refers to valley of shingle; index 2 refers to shingle's tooth.

Gloss retention was indistinguishable between the cool pigmented shingles and the conventional shingles.

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

Akbari gave a lecture titled "Cool Roofs for Urban Heat Island Mitigation," at the Andhra Pradesh Chambers of Commerce and Industry (FAPPCI), Hyderabad, India, July 2, 2005.

Akbari gave a lecture titled "Urban Heat Islands and Mitigation Technologies," at the International Institute for Information Technology, Hyderabad, India, July 4, 2005.

Akbari gave a lecture titled "Urban Heat Islands and Mitigation Technologies," at the Indian Institute of Technology, Mumbai, India, July 5, 2005.

2.7.2 Market Plan

The market plan was finalized. The plan was reviewed by several PAC members and all were in full agreement to implement the actions described in the report. The report outlines six market interventions available to the CEC to reduce or eliminate barriers that slow the market penetration of cool roofing products into the residential housing market. The market initiatives are: 1) regulate, 2) increase product selection, 3) label, 4) educate, 5) provide incentives and, 6) demonstrate performance. These interventions are targeted to reach manufacturers, distributors, retailers, architects, designers, builders, utilities, and consumers. The market plan was submitted to the CEC project manager in July 2005. **Task completed**.

2.7.3 Title 24 Code Revisions

**Task completed**.

## Management Issues

- Since the project has been extended through December 2006 to accommodate additional testing (Tasks 2.6.1, 2.6.2, and 2.6.3), Akbari and Scruton will discuss options to report progress on this testing to the CEC project manager.
- We have not yet obtained the formal approval of the requested no-cost extension (through December 2006) for the project.

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 7/31/2005 |
|---|---|---|---|---|---|---|
| 1 | **Preliminary Activities** | | | | | |
| 1.1 | Attend Kick Off Meeting<br>*Deliverables:*<br>• Written documentation of meeting agreements and all pertinent information (**Completed**)<br>• Initial schedule for the Project Advisory Committee meetings (**Completed**)<br>• 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<br>*Deliverables:*<br>• 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<br>*Deliverables:*<br>• Proposed Initial PAC Organization Membership List (**Completed**)<br>• Finalize Initial PAC Organization Membership List (**Completed**)<br>• PAC Meeting Schedule (**Completed)**<br>• Letters of Acceptance (**Completed)** | 6/1/02 | 5/17/02 | 9/1/02 | 9/1/02 | 100% |
| 2.2 | Software standardization<br>*Deliverables:*<br>• When applicable, all reports will include additional file formats that will be necessary to transfer deliverables to the CEC<br>• 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 7/31/2005 |
|---|---|---|---|---|---|---|
| 2.3 | PAC meetings (**Completed)**<br>*Deliverables:*<br>• Draft PAC meeting agenda(s) with back-up materials for agenda items<br>• Final PAC meeting agenda(s) with back-up materials for agenda items<br>• Schedule of Critical Project Reviews Draft PAC Meeting Summaries<br>• 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<br>*Deliverables:*<br>• Pigment Characterization Data Report (**Completed)** | 6/1/02 | 6/1/02 | 12/1/04 → 12/31/04 | 12/31/04 | 100% |
| 2.4.2 | Develop a Computer Program for Optimal Design of Cool Coatings<br>*Deliverables:*<br>• Computer Program (**Completed)** | 11/1/03 | 11/1/03 | 12/1/04 → 5/1/05 | 5/30/05 | 100% |
| 2.4.3 | Develop a Database of Cool-Colored Pigments<br>*Deliverables:*<br>• Electronic-format Pigment Database (**Completed)** | 6/1/03 | 7/1/03 | 6/1/05 → 12/31/04 | 12/31/04 | 100% |
| 2.5 | Development of prototype cool-colored roofing materials | | | | | |
| 2.5.1 | Review of Roofing Materials Manufacturing Methods<br>*Deliverables:*<br>• Methods of Fabrication and Coloring Report (**Completed)** | 6/1/02 | 6/1/02 | 6/1/03 | 4/1/05 | 100% |
| 2.5.2 | Design Innovative Methods for Application of Cool Coatings to Roofing Materials<br>*Deliverables:*<br>• Summary Coating Report **(Completed)**<br>• Prototype Performance Report **(Completed)** | 6/1/02 | 6/1/02 | 12/1/04 → 5/1/05 | 6/30/05 | ~ 100% |
| 2.5.3 | Accelerated Weathering Testing<br>*Deliverables:*<br>• 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 7/31/2005 |
|---|---|---|---|---|---|---|
| 2.6 | Field-testing and product useful life testing | | | | | |
| 2.6.1 | Building Energy-Use Measurements at California Demonstration Sites<br>*Deliverables:*<br>• Demonstration Site Test Plan (**Completed)**<br>• Test Site Report | 6/1/02 | 9/1/02 | 10/1/05 → 10/1/06 | | 92% |
| 2.6.2 | Materials Testing at Weathering Farms in California<br>*Deliverables:*<br>• Weathering Studies Report | 6/1/02 | 10/1/02 | 10/1/05 → 10/1/06 | | 90% |
| 2.6.3 | Steep-slope Assembly Testing at ORNL<br>*Deliverables:*<br>• Whole-Building Energy Model Validation<br>• Presentation at the Pacific Coast Builders Conference<br>• Steep Slope Assembly Test Report | 6/1/02 | 10/1/02 | 10/1/05 | | 93% |
| 2.6.4 | Product Useful Life Testing<br>*Deliverables:*<br>• Solar Reflectance Test Report **(Draft Prepared)** | 5/1/04 | 5/1/04 | 6/1/05 → 10/1/05 | | 97% |
| 2.7 | Technology transfer and market plan | | | | | |
| 2.7.1 | Technology Transfer (**Completed)**<br>*Deliverables:*<br>• Publication of results in industry magazines and refereed journal articles<br>• 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 | 6/1/05 | 100% |
| 2.7.2 | Market Plan<br>*Deliverables:*<br>• Market Plan(s) **(Completed)** | 5/1/05 | 4/1/05 | 6/1/05 | 7/10/05 | 100% |
| 2.7.3 | Title 24 Code Revisions<br>*Deliverables:*<br>• Document coordination with Cool Roofs Rating Council in monthly progress reports (**Completed)**<br>• Title 24 Database **(Completed)** | 6/1/02 | 5/16/02 | 6/1/05 | 6/30/05 | 100% |

**Project Tasks and Schedules (contd.)**

| Task | Task Title | Plan Start Date | Actual Start Date | Plan Finish Date | Actual Finish Date | % Completion as of 6/30/2005 |
|---|---|---|---|---|---|---|
| VII | Critical Project Review(s)<br>*Deliverables:*<br>• Minutes of the CPR meeting | | | | | |
| XII (C) | Monthly Progress Reports<br>*Deliverables:*<br>• Monthly Progress Reports (**Completed)** | 6/1/02 | 6/1/02 | 6/1/05 | | 106% (38/36) |
| XII (D) | Final Report<br>*Deliverables:*<br>• Final Report Outline<br>• Final Report | 3/1/05 → 3/31/06 | | 10/1/05 → 10/1/06 | | |
| | Final Meeting<br>*Deliverables:*<br>• Minutes of the final meeting | 10/15/05 | | 10/31/05 | | |