ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Stephen Wiel, Head
Energy Analysis Department
Environmental Energy Technologies Division

MS 90R4000
1 Cyclotron Road
Berkeley, CA 94720-8136

Tel. 510-486-5396
Fax: 510-486-6996
e-mail: Swiel@lbl.gov

July 17, 2003

To: Chris Scruton (CEC)

From: Steve Wiel

Subject: **Cool Roof Colored Materials**: Quarterly Progress Report for Second Quarter 2003

CC: Hashem Akbari, Paul Berdahl, Andre Desjarlais, Bill Miller, Ronnen Levinson

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

HIGHLIGHTS

- **BASF and MCA delivered roof exposure samples to ORNL.**
- **FERRO, Hanson Tile, Shepherd, Monier Life Tile all will support the Roof Tile Institute efforts in producing cool-colored concrete samples for the field exposure test sites.**
- **Mike Evans Construction and SMUD signed the Memorandum of Understanding (MOU) contributing demonstration homes for Task 2.6.1. Wiel visited Mike Evans of Evans Construction and toured Cavalli Hills, the new subdivision being built in Sacramento.**
- **CertainTeed Corporation (a leading manufacturer of asphalt shingle products) has requested entrance in our Cool Roofs Project. CertainTeed has expressed strong interest in the setup of a demonstration home in 2004.**
- **The project team visited two roofing factories in Southern California—Steelscape metal roll roofing in Rancho Cucamonga and MCA rooftile in Corona.**
- **A report summarizing our activities and analysis for Task 2.5.1 "Review of Roofing Materials Manufacturing Methods" is completed.**
- **Based on our pigment characterization work, ultramarine blue is a useful pigment for cool coating formulation. For example, it can be used mixed with a**

cool yellow complex inorganic pigment (Ni-Sb-Ti-O) to make a dark gray color with solar reflectance above 0.4.

Tasks

1.1 Attend Kick-Off MeetingThis 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

The next PAC meeting (September 11, 2003) will be held at LBNL, Berkeley. The future PAC meetings will be held at the following locations: March 4, 2004 meeting: CEC, Sacramento; September 10, 2004 meeting: ORNL; March 3, 2005 meeting: at an industrial partner facilities; and October 6, 2005 meeting: (the last one): CEC, Sacramento.

Planning for September 11, 2003 PAC meeting is started.

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance

In April 2003, we modified an inexpensive tabletop roller mill to simultaneously roll four small (59 cc) jars, and equipped it with a 12-hour timer. The mill can now be used to prepare in a controlled, reproducible fashion small quantities of paint from dry pigment powders, and also to mix prepared paints. We have begun to make paints from the 50 or so pigments provided by our industrial partners (Ferro, Shepherd), and to characterize the pigments from spectral measurements made on paint drawdowns.

While we succeeded in dispersing some of the dry pigments readily (the standard white being easy), other materials are proving more difficult and time consuming. We are consulting with the pigment manufacturers to improve our laboratory technique.

Intellectual property (IP) issues can hinder the free exchange of information between us and our industry partners. We signed one three-way non-disclosure agreement (NDA) to improve information flow and are working with the Tech Transfer and Patent departments at LBNL to arrange for the release of some internal LBNL information.

Our May activity focused on finalizing the theory and writing up the results of our 50 pigment characterizations to date, in preparation for a June submission of our work to a journal; and preparing to characterize another 30 or so pigments, and to characterize the performance of mixtures.

A. We have simplified the theory in a manner than allows us to estimate and correct for interface reflections (e.g., those that occur when light passed from air to paint, or vice-versa) before we calculate the Kubekla-Munk absorption (K) and scattering (S) coefficients. This makes our computational algorithm more efficient and robust. We have identified a number of minor issues, such as the observation of nominally (though not truly) negative film absorptances, indicating that there are subtleties associated with the spectrometer measurements that must be corrected.

B. The pigment characterization measurements have identified ultramarine blue as a useful pigment for cool coating formulation. It is a weakly scattering ("non-hiding") pigment that has strong absorption in the 500 to 700 nm range. It appears to have less infrared absorption than either phthalo blue or cobalt aluminate blue. By mixing it with a cool yellow pigment we were able to make a dark grey (bluish tint) color with a solar reflectance of nearly 50%. Ultramarine blue is inexpensive and very durable; however, it does have some sensitivity to acids.

C. We have begun to disperse Ferro pigments into a clear acrylic base using our small roller mill. While this has produced acceptable paints, the process is somewhat slow, taking up to a day to disperse some of the more difficult pigments (e.g., IR blacks). An extensive technical discussion with Ray Wing (Ferro Corporation) has suggested that an efficient and reliable way to obtain high quality acrylic paints based on Ferro's cool pigments would to be to start from pre-dispersed Ferro pigment concentrates available from the Consolidated Color Corporation. Ken Loye (Ferro) has arranged to send us concentrates for a dozen Ferro cool colors.

Our June activities followed five tracks: (1) refining our theory, and working to complete our journal paper on the subject; (2) computing pigment volume concentrations; (3) preparing and characterizing additional paints; (4) preparing and characterizing paint tints (mixtures of colors with white); and (5) resolving several optical measurement phenomena that appeared to yield unphysical results.

(1) **Theory refinement**. A major challenge in the calculation of Kubelka-Munk scattering and absorption coefficients is to correctly compute and correct for reflectances that occur at the interface of two media with different refractive indices (e.g., air and paint). This is particularly important when diffuse light passes from a paint film into the air, because the theoretical value of the interface reflectance is quite high (about 0.6), and actual values vary widely (measurements have yielded values of 0.2 to 0.7). Prior versions of our model have estimated this interface reflectance by varying its value to minimize the difference between a computed and measured value of the reflectance of a film over a black background. This technique has been reasonably successful, but the value of the interface reflectance so computed can be physically inconsistent with calculated values of the scattering and absorption coefficients. Hence, we have developed a new model that relates the interface reflectance to the scattering and absorption coefficients, and appears to provide much better agreement between measured and computed values of film reflectances over various backgrounds.

(2) **Computing pigment volume concentrations**. The physical nature of a paint film is typically described by specifying its pigment, vehicle (binder), thickness, and pigment volume concentration (PVC). The latter is the fraction of the paint film's volume occupied by pigment particles, and is a parameter by which paints are designed. We developed two techniques for calculating PVC. The first method estimates PVC from wet paint density, dry pigment density, binder density, and the extent of solvent loss when a paint film dries. It can be applied to any paint, but can become inaccurate when the pigment density is close to the binder density. The second method couples the above information with manufacturer reports of pigment loading in the wet paint (pigment mass/wet paint mass). This more accurate method is preferable when pigment loading data are available. We have used these methods to calculate PVCs for about half of the 60 or so mono pigment paints characterized to date, and will calculate the remaining PVCs once we obtain more data on the pigments contained in the remaining paints.

(3) **Preparing and characterizing additional paints**. The Ferro Corporation has provided us with 11 cool Ferro pigments in the form of pre-dispersed concentrates ("dispersions"). These concentrates can be let down (mixed with) a binder to produce paint, which is simpler than making paint by milling pigments into a binder. We have prepared and measured films drawn from paints made from these dispersions. The Shepherd Company has also arranged to provide us with dispersions of its cool color pigments, which we expect to receive and process next month.

(4) **Preparing and characterizing paint tints**. To prepare for the next stage of our project (using our model to predict the optical properties of paint mixtures), we have created and measured films made from mixtures of mono-pigments paints with white paint, or tints. We have created and

measured 1:4 and 1:9 (volume color: volume white) tints of about half of the mono-pigment artist color paints, and will tint the remaining mono-pigment paints next month.

(5) **Resolving optical measurement phenomena**. We have observed several puzzling phenomena when measuring the optical properties of paint films. The first occurs when the reflectance of an opaquely thick diffusing paint film (e.g., 2 mm of white paint) on a clear glass substrate is measured with a spectrometer equipped with an integrating sphere. We found that the reflectance measured with the film below the glass (solar reflectance=0.8) was significantly lower than that observed with the film above the glass (solar reflectance=0.9). This should not happen, because the glass and film have the same reflective index. We investigated this behavior by illuminating the film/glass system with a red laser beam, which demonstrated that when the film is behind the glass, some light travels laterally through the glass and does not enter the integrating sphere. This observation suggests that is may be necessary to take care of this phenomenon when measuring the reflectance of a paint film covered with a thick clear coat, since a thick clear coat may behave much like glass. A thin clear coat does not appear to cause difficulty.

The second puzzling phenomenon is that sometimes the spectrometer-measured reflectance and transmittance of a film sample sum to a value greater than one. This appears to be due to a minor design flaw common to integrating spheres related to the presence of two separate light detectors (one for UV and visible light, and another for near-infrared light). We will discuss this issue and its resolution in greater detail next month.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings

See Task 2.4.1. No major progress in Spring 2003.

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

On April 30, Berdahl, Levinson and Akbari visited the Steelscape metal roofing (in Rancho Cucamonga) and MCA rooftile (in Corona) plants in Southern California. The visit to Steelscape was arranged by Michelle Vondran from BASF, who accompanied us during the visit. Mr. Steve Perry, the plant manager at Steelscape, gave us a complete tour of the facilities. Steelscape has four major production lines: pickle line (cleaning of the hot band coil that arrives at the coating mill); cold reverse mill (reducing the thickness of the steel to specifications); metallic coating (production of steel rolls with zinc and aluminum metallic surface coatings); and paint line (painting the steel rolls). Of these four production lines, the paint line is that of direct interest to production of cool roofing materials. The painted metal rolls from Steelscape are used by other manufacturers to produce roofing materials. During the visit, we learned that it is feasible to produce novel cool-colored steel rolls through a two-layer coating approach (in some cases, the highly reflective metal surface under the colored coating would satisfy the condition of the reflective underlayer). It also appeared that the existing equipment for measuring the color of steel rolls may need to be expanded to afford capabilities for measuring reflectance in the near-infrared or solar spectra.

Our visit to MCA rooftile manufacturing plant was equally stimulating. We were hosted by Mr. Yoshihiro (Yoshi) Suzuki, the general manager of the plant. Yoshi gave us a complete tour of the facilities. The production of rooftiles at MCA plant goes through several basic stages: (1) preparation of the raw clay mix; (2) extrusion, cutting, and drying of clay tiles; (3) color-coating of the tiles; and (4) kiln-firing the raw dry clay tiles. MCA produces rooftiles in many different colors and has been a leader in application of cool-colored pigments on rooftiles. MCA also has a Devices & Services solar spectrum reflectometer for measuring the solar reflectance of products. We need to further investigate the applicability of the two-layer coating techniques to rooftiles.

We have prepared a draft report summarizing our activities and analysis for Task 2.5.1. The report focuses on manufacturing methods for colored roofing granules, shingles, metal roofing, and clay rooftiles. Our industrial partners who participated in the Task have reviewed and provided comments. We will shortly post the report on the web. Publication of this report will mark the completion of the task. In our review, we discovered that we also need to compile information on concrete rooftiles. In the upcoming months, we will make arrangements to visit a concrete rooftile plant.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials

We prepared samples for the testing and analysis of the two-layer technique for applying cool pigments on roofing materials. The near-infrared (NIR) reflectance of a NIR-transparent paint film can be raised through use of a NIR-reflective undercoat. We have prepared samples of various NIR-reflective undercoats, including white paints with high concentrations of titanium dioxide, metal paints based on aluminum flakes, and mica-flake paints. We have found that even fairly thin layers of white paint can be made NIR reflective if the pigment concentration is high. The NIR reflectance of aluminum-flake paints (about 0.6) was significantly lower than that of aluminum foil (about 0.9), suggesting either that the binder or the flakes were more absorptive than expected. The NIR reflectance of the mica-flake paints was comparable to the aluminum-flake paints.

2.5.3 Accelerated Weathering Testing

(No activity.)

2.6 Field-Testing and Product Useful Life Testing

Data acquisition equipment is on order and instrumented panels are being built for the demonstration homes. University of Tennessee at Knoxville (UTK) is searching the literature for mixed convection flow visualization studies that are similar in flow behavior to that occurring under a batten and counter batten roof construction.

CertainTeed Corporation has requested entrance in our Cool Roofs Project with the California Energy Commission. They are a leading manufacturer of asphalt shingle and other building products. Shiao, Ming L., principal research engineer at CertainTeed, is the company contact. He expressed strong interest in exposure of shingles and setup of a demonstration home in 2004.

The William Harrison Corporation built and shipped the exposure rack sets to the weathering sites in California. Reflectance and emittance measures were logged for the samples provided by BASF and MCA. ORNL is awaiting concrete tile samples from Monier LifeTile.

Steve Wiel visited Mike Evans of Evans construction. Steve reports: “Mike has permits for all 12 lots and is nearing completion of the common infrastructure as you can see in the following photos. He expects to start laying foundations for a few lots in two or three weeks. He hasn't yet decided how many to build now and how fast to finish out the project.

Mike is very pleased to be part of our project. I explained all about our CEC project, the project partners, the CEC, urban heat islands, and passive residential space conditioning (my past life as a solar home designer came in handy). I left him with tons of info (the project 2-and 6-pagers, our list of project stakeholders, a briefing on urban heat islands, LBNL propaganda -- see note below). He seemed pleased to learn that the only demo houses we're doing are with him.

The following photos show the subdivision from standing near the entrance to the one-block cul-de-sac and Mike and two of his workers. It's almost time to invite Chris Scruton and colleagues to visit. Mike is expecting that.”

2.6.1 Building Energy-Use Measurements at California Demonstration Sites

Mike Evans Construction and SMUD have signed and returned the Memorandum of Understanding (MOU) that establishes their willingness to coordinate work through ORNL for the setup and maintenance of data acquisition systems and instruments to be installed in the demonstration homes. LBNL was sent a copy of the signed MOU.

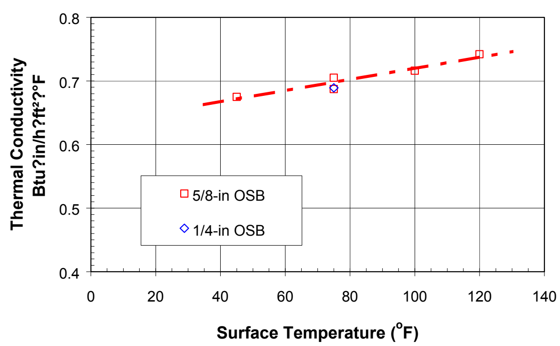


Figure 1. Thermal conductivity measures made for OSB.

The decking of the demonstration homes will be 5/8-in OSB. Typically 15/32-in OSB is used with batten construction for supporting concrete tile roofs. However, the 5/8-in OSB was selected because it is of sufficient thickness for obtaining accurate measures of heat flow from a 0.15-in thick heat flux transducer that will be embedded in the OSB. A 2-ft-square section of 5/8-in OSB was placed in a heat flux apparatus to determine the thermal conductivity of the material. Top temperature of the board was set at 45, 75, 100 and 120°F, which are typical temperatures observed by Parker, Sonne and Sherwin (2002) for roof decks covered by concrete tile. Results revealed that the thermal conductivity of OSB increases linearly with temperature (Fig. 1). A thinner ¼-in OSB board was also tested and found to have thermal conductance within ± 0.5% of the measures obtained for the thicker 5/8-in board (Fig. 1). The thinner board can therefore be used as a cover plate to hold the heat flux transducer in place. Shunting of heat flow will not occur because the two OSB boards have very close thermal conductivities. Shunting due to the differences in thermal conductance of the HFT and the OSB will be corrected by calibrating the instrumented 4-ft by 4-ft test panels using ASTM C518 (ASTM 1998). The thinner board will be on the underside of the deck to provide access if maintenance and or sensor replacement is required.

Parker, D.S., Sonne, J. K., Sherwin, J. R. 2002. "Comparative Evaluation of the Impact of Roofing Systems on Residential Cooling Energy Demand in Florida," in ACEEE Summer Study on Energy

Efficiency in Buildings, proceedings of American Council for an Energy Efficient Economy, Asilomar Conference Center in Pacific Grove, CA., Aug. 2002.

ASTM. 1998. Designation C518-98: Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. American Society for Testing and Materials, West Conshohocken, PA.

ORNL personnel fabricated 2-ft by 2-ft sandwich test panels for use in measuring the temperatures and heat flow through the roof decks of the demonstration homes. The sandwich panels and decks of the demonstration homes will be made of 5/8-in oriented strand board (OSB). Each sandwich panel is made of two sections equaling the same thickness as the rest of the deck. The two panels sandwich thermocouples and a heat flux transducer (HFT) for measuring thermal performance of the roofs. Two spare thermocouples are included for measuring the surface temperature of the tile and the bulk air temperature between the tile and the roof deck. The panels are in calibration to correct for shunting that occurs because of the differences in thermal conductance of the HFT and the OSB.

FERRO and Shepherd are both sending representatives this July, 03 to support the Roof Tile Institute with the manufacture of concrete tiles with CRCMs. FERRO is working with Hanson to produce CRCM tile for the demonstration homes, and Shepherd is working with Monier Life Tile to develop the concrete samples for the field exposure test sites. Both FERRO and Shepherd successfully matched the manufacturer's standard colors to colors containing the CRCMs.

2.6.2 Materials Testing at Weathering Farms in California

MCA clay tile samples were delivered to ORNL. Jerry Vandewater sent Monier LifeTile's cement mixture to Shepherd Color Company for blending the CRCM into the concrete tiles. Tom Steger of Shepherd volunteered technician support to help Monier make the 3.5-in square samples for the exposure sites. BASF has made the metal samples and the materials are in shipment to ORNL.

The William Harrison Corporation completed fabrication of the exposure rack sets. Shipment of the assemblies to the respective participating roofing manufacturers, Custom-Bilt, Steelscape, BASF, MCA and ELK is scheduled for the first week of June. The participating manufacturers will install the exposure rack sets at their facilities. ORNL personnel will install the two sets shipped to the California Irrigation Management Information System (CIMIS) sites located in Shasta and Imperial counties.

We completed measuring the initial reflectance and emittance on the BASF painted polyvinylidene fluoride (PVDF) metal samples and the MCA clay tile samples. The reflectance data for the seven colors provided by BASF show that the darker the color the greater is the %-increase in reflectance induced by the CRCMs. The brick red, charcoal gray, hartford green and slate bronze had reflectance %-increase exceeding 90% of the standard colors. Regal white showed the least gain, which is expected because the reflectance of the standard white is already high at 69%. We are planning to check several of these samples using spectrophotometers available at ORNL and at LBNL.

Table 1. Reflectance measures for samples of painted (PVDF) metal provided by BASF.

	Regal White	Rawhide	Slate Blue	Brick red	Charcoal Gray	Hartford Green	Slate Bronze
Standard	0.69	0.44	0.17	0.20	0.12	0.09	0.12
CRCM	0.74	0.57	0.28	0.37	0.31	0.27	0.26
Difference	0.05	0.13	0.11	0.17	0.19	0.18	0.14

Jerry Vandewater sent Monier LifeTile's cement mixture to Shepherd Color Company for blending the CRCM into the concrete tiles. Tom Steger of Shepherd reported that Shepherd was successful in blending the CRCM pigments into a top layer, and stated Shepherd was able to match CRCM colors to the standard colors supplied by Monier.

The William Harrison Corporation built and shipped seven exposure rack sets to California. Shipment of the assemblies to the respective participating roofing manufacturers, Custom-Bilt, Steelscape, BASF, MCA and ELK will be received June 16 through 20, 2003. The participating manufacturers will install the exposure rack sets at their facilities. ORNL personnel will install the two sets shipped to the California Irrigation Management Information System (CIMIS) sites located in Shasta and Imperial counties.

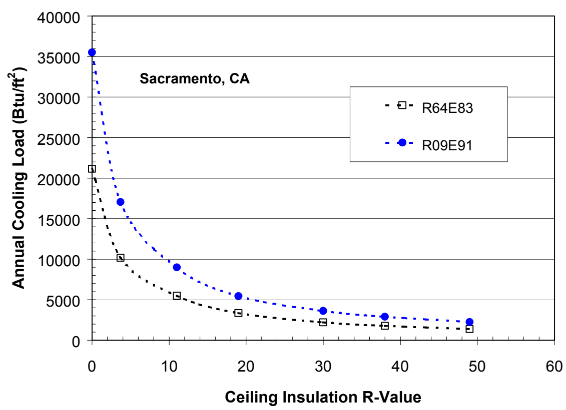
Ken Loyle of FERRO has arranged to work with John Quigley of Hanson Roof Tile to make the concrete tiles for the demonstration houses being built in Sacramento. Ken will spend about a week at the Rialto, CA plant to support manufacturer of the concrete tiles with CRCMs. John Quigley of Hanson agreed to forward samples of both low profile and S-Mission tile to Evan Construction for Mike Evans approval of the proposed roof materials.

The calibrations of the heat flux transducers embedded in oriented strand board sandwich panels were completed this period. The panels are being equipped with additional thermometry for measuring surface, air gap, deck and the underside deck temperatures in the demonstration homes. Data acquisition equipment is being programmed by Campbell Scientific with delivery of DAS equipment scheduled July 31, 03. Wim Boss of the Sacramento Municipal Utility District (SMUD) forwarded two power meters to Campbell Scientific for setup of the data collection programming. SMUD is working with LBNL and ORNL on DAS setup and is providing power instruments and setup support for the total and HVAC power metering of the demonstration homes. SMUD also will provide independent phone lines for each DAS to weekly download the field data.

2.6.3 Steep-slope Assembly Testing at ORNL

Computational fluid dynamic simulations were conducted to better understand the flow occurring within a batten constructed roof deck. The simulations were made for an open channel; however, both metal and tile roof manufacturers recommend the sealing the vent gap terminating at the ridge vent to prevent moisture damage from incoming rain. The Roof Tile Institute and the metal roofing consortiums have conducted wind uplift studies to measure the porosity of the roof cover. In fact the roof is designed porous to alleviate the underside air pressure and minimize uplift. Efforts are being made to acquire information on the flow coefficients measured from wind uplift testing. The data is extremely important for accounting for the dynamic behavior of the airflow occurring from the roof deck through gaps in the tile and back into the wind stream.

The AtticSim computational tool was used this reporting period to calculate the roof temperatures and ceiling heat flows expected for different levels of ceiling insulation in an attic having a roof pitch of 4-in of rise for 12-in of run (18.4° slope). Simulations were made for an asphalt shingle having reflectance of 9% and emittance of 91% (i.e., R09E91) and compared to a more reflective product having R64E83, typical measures for clay tile and PVDF painted metal with CRCMs. Typical meteorological year (TMY2) weather data averaged over a ten-year period for Sacramento, CA were used as inputs to the model. The annual cooling load entering the roof was reduced almost 40% by using CRCMs in an attic having R-19 ceiling insulation, Fig. 1. The maximum summertime attic air temperature was 160°F for the attic with asphalt shingles as opposed to an attic air temperature of 128°F for the roof with CRCM. As expected increasing the level of ceiling insulation caused the cooling load to converge (Fig. 1); however, even with R-50 ceiling insulation the CRCMs have reduced the cooling load by about 40% of the heat entering the asphalt shingle roof with R-50 ceiling insulation.



The Roof Tile Institute (RTI) is keenly interested in better understanding the effects of venting between the roof deck and tile. The convection heat transfer in this space may be mixed, and can significantly affect the thermal performance of the roof. All tiles whether direct nailed or installed on battens have a venting occurring up along the height and also transversely along the width of the roof. The flow poses significant reductions in heat transfer; however, measurement of the ventilation flow is very difficult especially with the tile purposely designed for air leakage to minimize wind uplift.

A data reduction scheme is proposed that enables the ventilation mass flow rate of air to be inferred from an energy balance in the vent cavity. Several heat flux transducers can be embedded in select test lanes for inferring the ventilation flow rate between the concrete tile and the roof deck (Fig.3). The bulk temperature gradient taken along the roof deck has the form:

$$\frac{dT_B}{dx} = \frac{h_R\left(T_{Roof} - T_B\right)}{\dot{m}C_P} + \frac{h_D\left(T_{Deck} - T_B\right)}{\dot{m}C_P} - \frac{kA}{\dot{m}C_P}\left(\frac{d^2T_B}{dx^2}\right)$$

The equation is for internal forced convection laminar flow. The numerators for the first two terms on the right hand side of the equation represent the heat flow into the cavity from the roof and the deck respectively and appropriate energy balances can be substituted for these terms to eliminate the unknown bulk, roof and deck temperatures that vary in the direction of flow. Hence, the equation can be manipulated into the following form to infer the mass flow rate of air in the vent cavity:

$$\dot{m}_{air} = \frac{\left(q''_{Roof} + q''_{Deck}\right)Width - kA\,\frac{d^2T_B}{dx^2}}{C_P\left(\frac{dT_B}{dx}\right)}$$

where q''_{Roof} is obtained from a surface energy balance of the roof and q''_{Deck} is obtained directly from the heat flux transducer measurements. The bulk temperature gradient is derived by taking the derivative of a curve fit to a series of thermocouple measurements taken in the vent gap along the length of the roof from soffitt to ridge (Fig. 3). The mass flow rate of air is calculated at each respective heat flux transducer station and based on continuity an assessment made of the leakage of airflow occurring from soffitt to ridge.

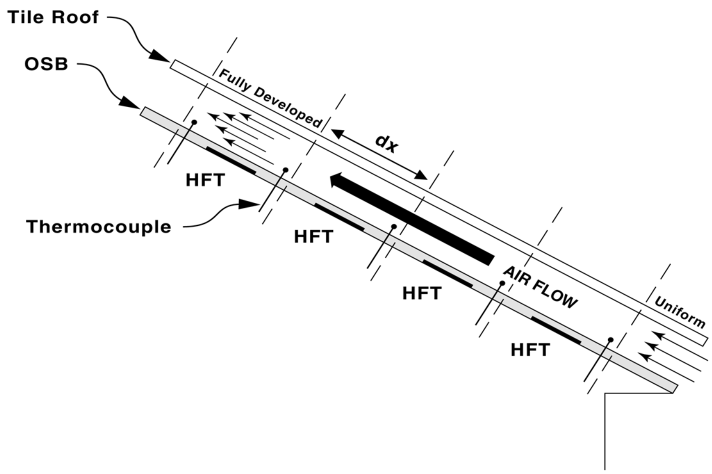
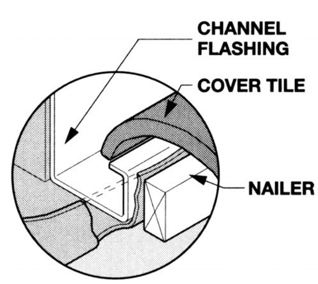


Fig. 3. Cross-section showing measurement scheme to infer airflow in vent gap.

Miller attended the Cool Metal Roofing Coalition (CMRC) meeting in January, 03 and finalized the agreement with the metal roof participants to use the existing steep-slope assembly for testing clay, tile and painted metal roofs having CRCM. The Roof Tile Institute (RTI) wants ORNL to measure the cool roof properties of five different tile assemblies that includes high profile "S" mission installed directly to the deck and over a batten and flat concrete tiles installed over a counter batten. ORNL made a commitment to test two metal roofs, one with and one without CRCM. We will, therefore, add two additional test lanes onto the existing assembly to accommodate testing of the painted metal materials. The painted metals will be direct nailed to the roof deck.

The configuration of concrete and clay tiles and painted metals selected for testing on the steep-slope assembly of the ERSA was reviewed with Jerry Vandewater of Monier Lifetile. All tiles whether direct nailed or installed on battens will have a venting occurring up along the height and transversely along the width of the test roofs. The Roof Tile Institute (RTI) had advised using a bead of foam between lanes to allow transverse venting effects only within a given test roof and not between test roofs. After further



discussion however, we decided to use a parapet partition with channel flashing (see figure) between each test roofs to eliminate any effects of transverse airflow from one test roof to another.

2.6.4 Product Useful Life Testing

(No activity.)

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

William Miller of ORNL, Danny Parker of the Florida Solar Energy Center and Hashem Akbari of the LBNL co-authored the paper "Painted Metal Roofs are Energy-Efficient, Durable and Sustainable," at the New Roofs for a New Century conference hosted by the Environmental Business Association of New York State. Akbari also presented a seminar on the subject of heat island, cool roofs, and green roof in the same conference.

2.7.2 Market Plan

(No activity.)

2.7.3 Title 24 Code Revisions

Levinson, Akbari, CEC, PG&E, Ely and Associates had many e-mail exchange discussing and fine-tuning the details of proposed Title 24 code language for application of reflective low-sloped on non-residential buildings.

Management Issues

- We hired a summer student to help us at the pigment characterization lab.

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 06/30/2003
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 shall include additional file formats that will be necessary to transfer deliverables to the CEC • When applicable, all reports shall 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 06/30/2003
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		33% (2/6)
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		~ 40%
2.4.2	Develop a Computer Program for Optimal Design of Cool Coatings *Deliverables:* • Computer Program	11/1/03		12/1/04		
2.4.3	Develop a Database of Cool-Colored Pigments *Deliverables:* • Electronic-format Pigment Database	6/1/03		6/1/05		
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		< 7%
2.5.3	Accelerated Weathering Testing *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	6/1/05		< 3%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 06/30/2003
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		10%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05		22%
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		14%
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 06/30/2003
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		36% (13/36)
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		