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January 17, 2003

To: Chris Scruton (CEC)

From: Steve Wiel

Subject: **Cool Roof Colored Materials**: Quarterly Progress Report for Third Quarter 2002

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

A summary of the status of Tasks and Deliverables as of December 31, 2002 is presented in Attachment 1.

HIGHLIGHTS

- We have selected seven sites for exposing metal, tile, and asphalt shingle roof products in the diverse climates of California.
- We have identified a company in Sacramento, Mike Evans Construction, who is interested in collaborating with us and is planning to build twelve homes within the Sacramento city limits. The walls will be insulated concrete foam (ICP) that the Sacramento Municipal Utility District (SMUD) is subsidizing in exchange for acquiring thermal performance data. Negotiations are continuing with both Mike Evans Construction and the Sacramento Municipal Utility District (SMUD) for selection of potential monitoring sites.
- Rick Olson and consortium members of the Roof Tile Institute submitted a written agreement to ORNL for the supply of roof material and labor to set up two demonstration homes in the Sacramento area.
- Custom-Bilt Metals agreed to supply both labor and painted metal roofing of the same color as used for the tile roofs for demonstration homes.
- We made significant theoretical and computational progress this quarter in our characterization of the optical properties of pigments.

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 essentially completed. We have added two new members to the PAC (the updated list of PAC members is attached (Attachment 2):

i) Steven Harris, Certification Manager of the Quality Auditing Institute, representing the Cedar Shake and Shingle Bureau (CSSB).

ii) Aaron Backer, representing the DuPont Titanium Technologies.

2.2 Software Standardization
(No activity.)

2.3 PAC Meetings
Planning for the second PAC meeting will start in January 2003.

2.4 Development of Cool Colored Coatings

2.4.1 Identify and Characterize Pigments with High Solar Reflectance
Pigment characterization this quarter focused on analysis of the optical properties of the 51 pigments measured to date. Our model for prediction of Kubelka-Munk scattering and absorption coefficients is being revised to (a) better account for the effects of interface reflection, and (b) incorporate contributions made by other researchers in the field.

We made significant theoretical and computational progress this quarter in our characterization of the optical properties of pigments. We revised the theory used to determine the Kubelka-Munk scattering and absorption coefficients to base the calculation on one measurement of reflectance and one measurement of transmittance, rather than two measurements of reflectance, allowing us to better handle the common case of nearly-opaque films. We have documented this theory in a draft of a journal paper in progress. We have also gained insight into the important phenomenon of reflection due to change in refractive index at a smooth interface, which can strongly influence paint-film reflectance. The theory has been written up as part of a journal paper being drafted, and the optical property calculations are in progress.

Jeff Nixon of Shepherd provided us some of the details of their optical testing procedures for cool pigmented PVDF acrylic coatings on galvalume metal roofing. A primer coat (acrylic expoxy, 0.3 mils) contains an SrCrO4 yellow pigment for adhesion and corrosion inhibition. Then they add a 10 mil wet coating (70 % minimum PVDF) containing the cool pigment, which dries to a thickness of about 5 mils. This is a thicker coating than what is used in production; they want a thick coating to reduce the sensitivity to the substrate. (The coating is partly translucent.) He observed that for standard samples, sample preparation (good pigment dispersion) is important and that the use of tint ladders (mixtures with white and/or black) can improve accuracy. Several companies sell software for colored coating design, but the software does not (yet) treat the infrared part of the spectrum.

After reviewing the papers by French et al., we made measurements on several pigmented samples using their procedure, namely spectral reflectance and spectral

transmittance, with the specular (unscattered) component excluded. While there are advantages to the French et al. approach under certain special circumstances, such as the measurement of the reflectance of an absorbing (black) pigment layer, overall there is no net benefit for us to change our measurement procedure.

Pigment characterization this quarter focused on analysis of the optical properties of the 51 pigments measured to date. Our model for prediction of Kubelka-Munk scattering and absorption coefficients is being revised to (a) better account for the effects of interface reflection, and (b) incorporate contributions made by other researchers in the field. We are preparing a journal paper detailing our efforts to date.

We are considering making additional spectrometer measurements on a number of samples to add to our data set. These would be diffuse reflectance and transmittance, with the specular component excluded. These measurements are the type used by McNeil and French.

The quinacridone class of red and maroon organic pigments has appeal as cool colored pigments. These pigments have very little near-infrared absorption and are sufficiently durable to be used in automobile coatings. We are seeking information from Ciba Specialty Chemicals on the maximum use temperature of these materials to see if they could be incorporated into roofing granules. We also learned of another organic pigment that is used in the automotive market – benzimidazdone yellow (PY=Pigment Yellow 97, and PY 154).

We identified a commercial laboratory that is capable of measuring organic and black carbon separately (Sunset Laboratory, Forest Grove, Oregon). This capability may be useful in the analysis of soil deposits on roofing in the future.

2.4.2 Develop a Computer Program for Optimal Design of Cool Coatings
The algorithms being developed under Task 2.4.1 will be used in this task.

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
The review of literature is progressing on schedule. Our industrial partners will be sharing manufacturing process information with us. ISP Minerals has provided some useful information regarding manufacturing shingle granules. We are also in the process of making arrangements with BASF, 3M, and ISP Minerals to visit a few industrial sites (manufacturing of roofing materials) in the vicinity of the Bay Area.

2.5.2 Design Innovative Methods for Application of Cool Coatings to Roofing Materials
We prepared a few samples and measured their optical properties. 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
Rick Olson and consortium members of the Roof Tile Institute are in the process of selecting and preparing cement tile roof products for field-testing on the Envelope Systems Research Apparatus (ESRA) demonstration homes and for the weathering sites. Evans Construction has plans for building 12 new houses this upcoming fiscal year and ORNL, Hanson Tile and Custom-Bilt Metal have committed to supplying tile and metal roof materials for four of the new homes.

Rick Olson and consortium members of the Roof Tile Institute submitted a written agreement to ORNL for the supply of roof material and labor for two of the demonstration homes in the Sacramento area. The first roof will have a medium profile concrete tile with the black, slate bronze or charcoal gray Ferro oxide. The roof will be installed on a batten system. The second roof will be installed with identical conditions except the tile will not have the Ferro oxide. Hanson in Northern Ca will manufacture the tile for these roofs. Custom-Bilt Metals has also made a similar agreement to supply both labor and metal roofing of the same color as used for the tile roofs for two other demonstration homes.

Final approval is still pending for use of the homes in the Sacramento subdivision being built by Evans Construction. Land use agreements were granted for setup of the exposure racks in seven sites across the state of California.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites
A written test plan was prepared for the proposed approach to setup and test CRCM at the California demonstration sites, at the ORNL on the ESRA and at the California weathering farms. LBNL and the Florida Solar Research Center reviewed the plan and ORNL incorporated appropriate comments into the plan.

Archie Mulligan, Executive Director for Habitat for Humanity (HFH), specified the start dates for construction of the new Habitat homes in Sacramento CA. (Table 1). Unfortunately, none of these homes will be on adjacent lots, and therefore we would not be able to conduct side-by-side field comparison of a standard roof color to one with “Cool Roof Colored Materials” (CRCM). However, Mulligan did state that Habitat owns a half-acre lot in south Sacramento where four homes each with composition shingle roofing will be placed. One home is presently onsite. Two of the other houses were recently blitz-built, and are awaiting placement on the lot in south Sacramento. The fourth house is slated for construction in December 2002.

Table 1. The start date and number of homes to be built by HfH in FY03.

Construction Start	Number of Homes
Dec., 2002	1
Jan., 2003	1
Mar., 2003	1
Apr., 2003	1
July, 2003	2

HFH must submit a permit to the Sacramento municipality to approve subdividing the lot into four parcels for the four homes. Mulligan stated the lead-time for approval is about 5 months; therefore, ORNL is seeking other options with local and national contractors for potential demonstration sites just in case lead-time expands or approval for splitting the lot is denied.

Terri-Lei Robertson of Tesh Construction, Larry Burkhardt, president and CEO of the Economic Resource Council in Grass Valley, and the Sacramento Municipal Utility District (SMUD) are all interested in working with ORNL and LBNL. Mike Evans Construction has plans to build twelve homes within the Sacramento city limits. Six homes will be built simultaneously starting in March, 03. Sewer and water are already installed, and architectural house plans are in review. Evans will finish the subdivision the following year with six more homes. Houses will have footprints of about 1300, 1600 or 1900 square feet. The walls will be insulated concrete foam (ICP) that SMUD is subsidizing in exchange for acquiring thermal performance data. The builder recently spoke with Hanson Roof Tile, Custom-Bilt Metals and ORNL, and is both interested and willing to work with ORNL and LBNL. This is an excellent opportunity to pursue, because of location and because of the possible synergistic involvement with SMUD, who is subsidizing Evans Construction in exchange for acquiring thermal performance data of insulated concrete foam (ICP) walls. We are interested in the roofs. Hence, we are discussing with SMUD the possibility of combining the two initiatives and working together on the performance of the building envelope.

Evans Construction prefers minimal intrusions from data acquisition systems (DAS) and monitoring equipment. They want potential homebuyers to be enthusiastic about their new home, and not dissatisfied with unsightly DAS equipment. Therefore, ORNL and SMUD are working toward a common data acquisition system for measuring wall, roof and HVAC performance.

2.6.2 Materials Testing at Weathering Farms in California

California has sixteen zones that cover the broad and diverse range of climates ranging from alpine to desert conditions. The climate zones are based on temperature, weather and energy use. The Energy Commission established each of the 16 climate zones to represent a geographic area with an established energy budget that specifies the maximum amount of energy that a building or portion of a building can be designed to consume per year. Several candidate sites were identified; from them we selected seven sites to capture the effects of weather, urban pollution and population.

Custom-Bilt Metal, Steelscape, BASF, MCA Clay Tile and Elk Corp. will field test CRCM at their respective manufacturing facilities (Table 2). The California population is expanding rapidly in the Central Valley and around the LA basin, and the sites with Custom-Bilt and Elk will capture the effects of weather, urban pollution and the expanding population. These areas reflect a market with many new homes. Weathering sites with Steelscape, BASF and MCA Clay Tile are located in existing densely populated areas, and represent the market for re-roofing existing homes. Samples will also be exposed near weather stations maintained by the California Irrigation Management Information System (CIMIS). Sites in McArthur and Meloland, CA were selected for acquiring exposure data in the more extreme climates. McArthur is located in the moderate alpine climate of northern California

(climate zone 16); Meloland is in the extremely hot desert climate of southern California bordering Mexico (climate zone 18).

Table 2. Weathering Sites for exposing the CRCMs in the diverse climates of California.

Company	Contact	Street Address	City	ZIP Code	County	Climate Zone
Custom-Bilt	Don Bonnington (916) 372-7696	1347 Shore Street	Sacramento	95691	Sacramento	12
Steelscape	Bruce Hopkins (510) 262-4858	2995 Atlas Road	Richmond	94806	Contra Costa	3
BASF	Michelle Vondran (909) 825-6292 Ext 309	1231 S. Lincoln St.	Colton	92324	San Bernadino	10
Maruhachi Ceramics of America	Yoshihiro Suzuki (909) 736-6221	1985 Sampson Ave.	Corona	92879	Riverside	10
ELK Corporation	Gus Freshwater (661) 391-3906	6200 Zerker Road	Shafter	93263	Kern	13
Department of Water Resources CIMIS	Jamie Dubay (530) 529-7367		McArthur		Shasta	16
Department of Water Resources CIMIS	Sergio Fierro (818) 543-4652	UC Davis Extension site	Meloland		Imperial	18

The CIMIS web site http://www.cimis.water.ca.gov/ has current weather data for use in correlating the loss of reflectance of samples exposed at the field sites in Table 2. In fact, CIMIS has 118 computerized weather stations acquiring hourly data of solar irradiance, ambient air temperature and relative humidity as well as wind speed, wind direction and precipitation for helping agricultural growers judge when to irrigate and how much water to apply. Hourly, daily, weekly and or monthly data can be down loaded for developing correlations for the loss of reflectance.

We (ORNL) have received approval from the California Department of Water Resources (DWR) to setup exposure racks in the vicinity of weather stations maintained by the California Irrigation Management Information System (CIMIS). A Memorandum of Understanding was forwarded to the DWR to define placement and maintenance requirements for the racks. The DWR wants their district DWR representatives to be informed of any site visits or maintenance. The DWR agreed to have their technicians check the exposure site as part of their monthly check of meteorological instruments. They will also support us with the retrieval and replacement of samples for scheduled measurements of reflectance and emittance.

The exposure racks will each be 5.5-ft high by 9-ft long. A rack will be divided into three sections having respective slopes of 2-, 4- and 8-in of rise for 12-in of run. Each section can hold two sub-assemblies that are easily removed from the rack for

shipment to ORNL. All sub-assemblies will be designed to have 6 rows of samples with 34-in of usable space in each row. Sample size will be 3.5-in by 3.5-in, a size that LBNL's Perkin-Elmer Lambda 900 spectrophotometer can easily accommodate.

Our plan is to start field-testing concrete tile, clay tile, and painted metal in the exposure racks in March 2003. The racks will have ample room when additional asphalt shingles are ready for testing. MCA will supply samples of clay tile, and Monier Life Tile will supply samples of cement tile. BASF will supply all the painted metal samples. We will conduct side-by-side testing of seven different painted metal colors with standard pigments and also with CRCM blended by BASF. A similar approach will be tried with the concrete tile; however, MCA manufactures clay tile only with the CRCM so comparable reflective and non-reflective samples are not available.

2.6.3 Steep-slope Assembly Testing at ORNL

A safety review plan was completed this quarter for identifying potential hazards for setup of the steep-slope assembly. The plan is required by the Safe Work Practices Research Safety (RSS) of ORNL prior to the start of construction by an offsite vendor.

The metal consortiums working with ORNL have completed their painted metal study conducted at ORNL, and have agreed to let ORNL use the existing steep-slope assembly for testing tile and metal roof products painted with CRCMs.

The tile consortium wants a steep-sloped roof assembly for measuring the cool roof properties of 5 different tile assemblies. Test sections will be 4 feet wide by 14 feet high, and will be configured with the tiles listed in Table 3.

The deck configuration for installation will be left to right – 1,2,5,4,3 . This will allow the best opportunity for tile heights to match up in helping to seal the individual cell roof areas. A small bead of foam will be placed vertically between the 5 panel areas. A bead of foam will be applied between each panel section to limit airflow between panels.

Table 3. Clay and Concrete tile proposed by the Roof Tile Institute for the test stand at ORNL.

	Type of Tile	Producer	Application	Color
1	Clay "S"	MCA	Direct Deck	Terracotta
2	Concrete Medium	Hanson	Direct Deck	Black -Ferro
3	Concrete "S"	Eagle	Batten	Slurry Terra Cotta
4	Concrete Flat	Monier Life Tile	Counter Batten	Brown
5	Concrete Medium	Monier Life Tile	Direct Deck w/foam	Slurry Terra Cotta

2.6.4 Product Useful Life Testing

(No activity.)

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

Akbari and Desjarlais presented seminars on application of cool roofs in California in a meeting of the Roofing Industry Committee on Weather Issues (RICOWI) on November 15, 2002.

Miller attended the National Coil Coaters Associations (NCCA) annual meeting in St. Louis and presented results on the loss of reflectance of painted and unpainted metal roof products as affected by three years of weathering exposure. The presentation also addressed the performance of complex inorganic color pigments in painted polyvinylidene fluoride coatings applied to painted metal.

PRA International Center for Coatings Technology accepted a paper, "Energy and Durability Performance of Complex Inorganic Color Pigments used in Polyvinylidene Fluoride Coatings," from Miller for presentation at their upcoming Fluorine in Coatings V conference call for papers to be held in Orlando, FL. on January 21, 2003. John Lun of Ferro Corporation will attend and make the presentation at the conference.

2.7.2 Market Plan
(No activity.)

2.7.3 Title 24 Code Revisions
Based on some comments made by roofing contractors at November 15 meeting of RICOWI, Pennington and Akbari made modifications to the proposal for revision of Title 24 for cool roofs on existing non-residential low-sloped roofs.

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 12/31/2002
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		98%
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 12/31/2002
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		13% (1/6)
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		~ 17%
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		~ 40%
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%
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 12/31/2002
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		5%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05		10%
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		~ 10%
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		~ 3%
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 12/31/2002
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		19% (7/36)
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		

Attachment 2.

Update list of Project Advisory Committee members.

Member	Company	E_mail	Tel No.
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