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September 9, 2005

To: Chris Scruton (CEC)
From: Hashem Akbari
Subject: **Cool Roof Colored Materials**: Monthly Progress Report for August 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 August 31, 2005 is presented in Attachment 1.

HIGHLIGHTS

- We are working to complete deliverables for Tasks 2.5.3 "Accelerated Weathering", Task 2.6.3 "Steep-Slope Assembly Testing at ORNL", and Task 2.6.4 "Product Useful Life Testing".
- Lou Hahn of Elk Corp visited ORNL to review the thermal measurements made on test roofs with asphalt shingles exposed at ORNL and on the demonstration homes in Redding, CA.
- Elk is willing to supply information and materials and work with ORNL and LBNL to report on the cool colored asphalt shingle demonstrations at the June 2006 Pacific Coast Builders Conference. Either an educational program or a paper will be presented pending review by the PCBC staff, which they will complete in Jan 2006.

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. Our paper "Methods of Creating Solar-Reflective Nonwhite Surfaces and their Application to Residential Roofing Materials" was accepted for publication by Solar Energy Materials & Solar Cells.

2.5.3 Accelerated Weathering Testing
Work on the manuscript on accelerated weathering has been resumed. An extensive bibliography was compiled earlier. Recent newsletters by Atlas, Materials Testing Solutions have been identified as good sources on the current state of the art.

Often (for example, especially for polymers), ultraviolet radiation is a key weathering influence. Some of the current work in the area of testing entails ensuring a better match between natural UV spectra and those produced by accelerated test equipment.

Earlier in this project, accelerated weathering data on roofing materials were obtained from BASF and Ferro. Currently data are being collected and provided to ORNL by 3M and Shepherd Color Company. Both companies continue to expose roof samples with and without cool colored materials to accelerated fluorescent light and Xenon-arc irradiance. Shepherd and 3M have logged over 2000 hours of exposure. A tabulation of the solar reflectance, total color change and surface gloss are provided in Appendix A. There are no noticeable drops in solar reflectance for either fluorescent or Xenon-arc exposures (Tables A1 and A2). Some of the cool colored clay tiles showed losses in solar reflectance from 1000 hours to 2000 hours of exposure. As example, the natural red clay tile (code 241) with cool colored coatings dropped from an initial solar reflectance of 0.44 to 0.40 after 1000 hours and continued to drop to 0.38 after 2000 hours. Gloss retention remains indistinguishable among the cool colored painted metals, the cool pigmented asphalt shingles and their respective counterparts having conventional pigments. Changes in total color (ΔE) were almost all less than 2.0 color units with exception of the natural red and ironwood clay tiles.

2.6 Field-Testing and Product Useful Life Testing
Lou Hahn of Elk Corp visited ORNL to review the thermal measurements made on test roofs with asphalt shingles exposed at ORNL and on the demonstration homes in Redding, CA. The Metal Construction Association (MCA) spent one day of their semi-annual conference with ORNL and reviewed the “cool roof” work among several other projects.

2.6.1 Building Energy-Use Measurements at California Demonstration Sites

Asphalt Shingle Demonstrations: Lou Hahn, Technology Center Manager for Elk Corporation, visited ORNL to review and discuss the data acquired on the Redding, CA demonstrations. Mr. Hahn was very interested in the deck temperatures and the heat flows penetrating the roof decks for the pair of homes with and without cool colored materials. July and August ambient air temperatures at solar noon exceeded 110°F (45°C) in Redding, CA (Fig. 1). Similar data for the ongoing field tests at the ORNL campus showed peak temperatures very close to those for the shingles exposed in Redding. During late July, the conventional shingles exposed in Oak Ridge had peak temperatures of about 165°F as compared to peak shingle temperatures of about 170°F in Redding for the same conventional shingle (Fig. 1). The difference in surface temperature between the conventional and cool colored shingle is about 10°F for both locations. Air temperature in late July was about 20°F cooler in Oak Ridge; however, the steep-slope assembly in Oak Ridge is oriented south facing and receives a more intense irradiance than that incident on the Redding homes.

The return air temperatures for the two homes are quite often different, implying that the thermostats are at different set point temperatures. The house with cool colored shingles on Loggerhead Street has return air temperature that are always below those measured for the other home with conventional shingles (Fig 2).

The realtor for these homes, Jerry Wagar, had requested the homeowners operate their thermostats at the same set point temperature of 70°F; further contacts are planned to correct the mismatch between the two homes. However, the effect of the two different thermostat settings causes the house on Loggerhead to consume more air-conditioning power than the house on EEL Street. The data for Figure 1 and 2 was taken the last week of July (data week starting July 29th) and despite the reductions in roof heat flows the air conditioners are using about 12% more energy that the home on EEL Street (see Table 1). However, a couple weeks later (tan highlight for week starting Aug 12th) the Loggerhead home with cool colored shingles used 12% less air conditioning energy than the home with conventional shingles. The results show the strong effects of occupancy habits and comfort cooling preferences on residential energy consumption.

Table 1. HVAC Power for Homes in Redding CA

	Air-Conditioner Power (kWh)	
Date	Eel Street (Conventional Shingle)	Loggerhead Street (CRCM shingle)
7/1/2005	172.5	86.1
7/8/2005	123.0	198.7
7/15/2005	194.0	221.1
7/22/2005	47.2	204.4
7/29/2005	183.8	209.0
8/5/2005	173.1	216.5
8/12/2005	142.1	123.5
8/19/2005	64.7	178.2
8/26/2005	139.1	148.0

2.6.2 Materials Testing at Weathering Farms in California

All samples continue to be exposed in the seven weathering sites in California.

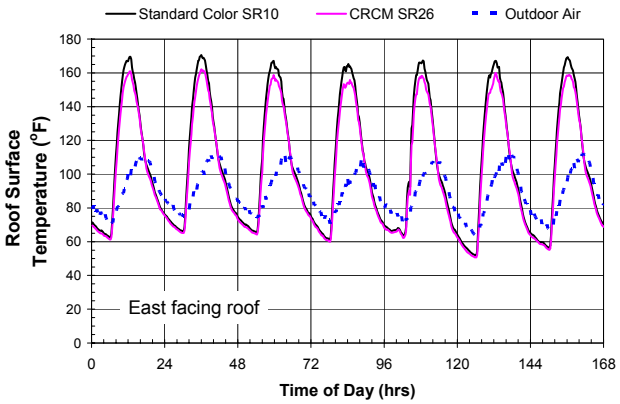

Figure 1. The pair of demonstration homes in Redding, CA with asphalt shingle roofs. Underside temperatures of the shingles show the advantage of cool colored roofing materials.

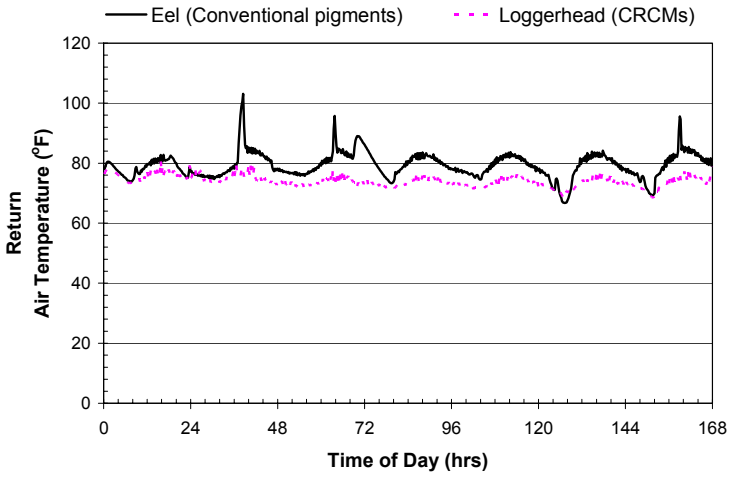

Figure 2. The difference in return air temperatures between the two Redding homes shows that the thermostat settings are different.

2.6.3 Steep-slope Assembly Testing at ORNL

Efforts are in progress to complete a report for the testing of the clay and concrete tile roofs that satisfies Deliverable 2.6.3. A numerical simulation was performed for the air gap formed by the underside of the tile roofs and the OSB deck. The velocity profile was generated using FEMLAB and is shown in Figure 3. The right side of the plot is the underside of the roof and shows the maximum air velocity nearer to the heated wall which agrees with boundary layer theory. The bulk air velocity was computed as 0.6 ft per sec, which agrees with several of the tracer gas tests used to measure the bulk velocity. These results along with the data reductions from previously reported

experimental data verify that the tracer measurements are reasonable and can be used to further formulate AtticSim for ventilating the roof deck.

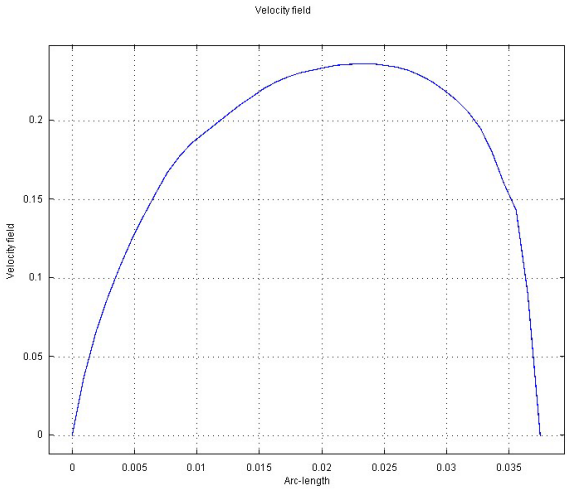

Figure 3. Normalized velocity profile in the air channel made by the underside of the S-Mission clay tile and the OSB roof deck.

2.6.4 Product Useful Life Testing

Our review paper "Weathering of Roofing Materials-An Overview," by Berdahl, Akbari, Levinson, and Miller, was substantially completed in July. We are in the process of reviewing and finalizing the paper.

2.7 Technology transfer and market plan

2.7.1 Technology Transfer

The Metal Construction Association (MCA) spent one day of their semi-annual conference meeting with the Building Envelope Program (BEP) staff at ORNL. The BEP hosted over 150 MCA members from the United States, Canada, Mexico, Germany, and France. W. Miler gave presentation of the residential “cool roof” field studies being conducted at ORNL and described the benefits of cool colored materials and venting of the roof deck.

2.7.2 Market Plan

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.

Appendix A
Accelerated Fluorescent Light Test Data

Shepherd Color Company is conducting the fluorescent light exposure testing according to ASTM G154-04 using a 340 nm lamp for daylight UV irradiance. Exposure conditions are 8 hours of UV light at 60°C black panel temperature followed by 4 hours of condensation at 50°C. Total color change is measured using a Hunter Labscan instrument. Solar reflectance is measured using the Device & Services reflectometer. Gloss is measured using a BYK Gardner Micro-TRI-gloss device.

Table A1. Solar reflectance, Total Color Change and the Gloss of Roof Samples Exposed to Fluorescent Light at Shepherd Color Company.

		Initial Measures		1000 hours of Fluorescent light exposure			2000 hours of Fluorescent light exposure		
Material Code	Roof Product	Solar Reflectance	Gloss	Solar Reflectance	Total ΔE	Gloss	Solar Reflectance	Total ΔE	Gloss
Natural Red Cool 140	Clay tile	44.6	2.0	44.6	1.4	2.0	45.0	0.5	2.0
Natural Red Cool 141		44.8	2.0	45.0	0.8	2.0	45.0	0.3	2.0
Natural Red Cool 142		44.7	2.0	44.6	0.7	2.0	45.0	0.7	2.0
Ironwood Cool 146		25.9	1.0	25.9	0.2	1.0	26.0	0.2	1.0
Ironwood Cool 147		27.3	1.0	26.8	0.5	1.0	27.0	0.5	1.0
Ironwood Cool 148		26.7	1.0	26.4	0.5	1.0	26.0	0.6	1.0
872T3 Slate Bronze Cool 124	PVDF Metal	26.0	28.0	25.8	0.3	29.0	26.0	0.5	29.0
872T3 Slate Bronze Cool 125		25.9	28.0	25.7	0.4	28.0	26.0	0.7	27.0
872T3 Slate Bronze Cool 126		25.9	28.0	25.8	0.3	29.0	26.0	0.5	29.0
815T119 Slate Bronze Std 127		11.7	28.0	11.7	0.4	28.0	12.0	0.6	28.0
872R10 Brick Red Cool 112		36.7	36.0	36.0	0.3	36.0	35.0	1.2	36.0
872R10 Brick Red Cool 113		36.6	37.0	36.3	0.2	37.0	36.0	0.3	37.0
872R10 Brick Red Cool 114		36.6	36.0	36.2	0.3	37.0	36.0	0.4	36.0
815R71 Brick Red Std 115		19.0	29.0	19.2	0.8	30.0	19.0	0.8	30.0
Terracotta M3308	Concrete tile	30.8	8.0	30.1	1.7	9.0	30.0	1.6	7.0
Terracotta IR3308		46.9	11.0	45.9	1.6	14.0	46.0	1.3	6.0
Chocolate M3808		12.9	4.0	12.1	1.3	4.0	12.0	1.3	4.0
Chocolate IR3808		39.2	12.0	38.2	1.6	12.0	38.0	1.9	7.0
Cool IRR - A1	Asphalt Shingle	25.8	0.0	25.5	0.8	0.0	26.0	1.0	0.0
Cool IRR - A2		25.3	0.0	24.6	1.8	0.0	25.0	1.1	0.0
Std - B1		6.7	0.0	7.2	1.3	0.0	7.0	1.6	0.0
Std - B2		7.4	0.0	7.7	0.3	0.0	8.0	0.2	0.0
Cool - C1		26.9	0.0	26.8	2.0	0.0	27.0	1.8	0.0
Cool - C2		26.1	0.0	25.2	2.5	0.0	25.0	1.2	0.0
Std - D1		10.0	0.0	10.5	1.2	0.0	11.0	0.7	0.0
Std - D2		11.3	0.0	11.5	0.2	0.0	11.0	0.9	0.0
Std Premium - E1		6.5	0.0	6.8	1.1	0.0	8.0	2.3	0.0
Std Premium - E2		6.5	0.0	6.4	1.0	0.0	7.0	1.8	0.0
Cool Premium - F1		23.6	0.0	23.8	0.6	0.0	24.0	0.3	0.0
Cool Premium - F2		25.0	0.0	23.8	0.6	0.0	25.0	0.6	0.0

[1]A1,B1,C1,D1,E1,F1 are samples of asphalt shingles cut from valley of shingle

[2]A2,B2,C2,D2,E2,F2 are samples of asphalt shingles cut from tooth of shingle

[3]Premium refers to a top-of-the-line shingle having a 50 year warranty

- American Society for Testing and Materials (ASTM). 2005. Designation G 154-04: Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials. West Conshohocken, Pa.: American Society for Testing and Materials.

Appendix A
Xenon-Arc Exposure Test Data

Xenon-arc exposure testing is \being conducted according to ASTM G155-04a. A daylight filters is used to simulate daylight UV irradiance. The exposure conditions require 102 minutes of light at 63°C black panel temperature followed by 18 minutes of light with condensation. Panel temperature is not controlled during condensation. A radiometer monitors the irradiance and the measurement is used in a feed back control loop to control the radiant energy incident on the samples. Total color change is measured using a Hunter Labscan instrument. Solar reflectance is measured using the Device & Services reflectometer. Gloss is measured using a BYK Gardner Micro-TRI-gloss device.

Table A2. Solar Reflectance, Total Color Change And Gloss Of Roof Samples Exposed To Xenon-Arc Exposure At 3M Minerals Company.

		Initial Measures		1000 hours of Xenon-Arc exposure			2000 hours of Xenon-Arc exposure		
Material Code	Roof Product	Solar Reflectance	Gloss	Solar Reflectance	Total ΔE	Gloss	Solar Reflectance	Total ΔE	Gloss
Natural Red Cool 240	Clay tile	43.3	1.8	44.2	5.5	1.3	43.6	3.4	1.2
Natural Red Cool 241		43.5	1.9	40.4	3.9	1.7	37.9	6.5	1.7
Natural Red Cool 242		43.8	1.8	36.7	7.7	1.4	34.4	8.7	1.3
Ironwood Cool 246		25.5	0.6	20.6	6.8	0.5	21.0	6.1	0.5
Ironwood Cool 247		26.5	0.6	27.5	1.5	0.6	27.4	1.8	0.6
Ironwood Cool 248		25.8	0.6	23.6	4.4	0.5	24.1	4.3	0.5
872T3 Slate Bronze Cool 224	PVDF Metal	25.3	29.3	26.6	0.2	29.3	26.6	0.7	27.4
872T3 Slate Bronze Cool 225		25.3	29.0	26.5	0.2	28.9	26.7	0.8	27.1
872T3 Slate Bronze Cool 226		25.2	27.2	26.4	0.3	27.1	26.7	0.6	26.1
815T119 Slate Bronze Std 227		11.5	29.6	11.7	0.2	28.9	12.0	0.3	27.9
872R10 Brick Red Cool 212		35.9	37.6	37.4	0.3	36.9	37.5	0.5	35.4
872R10 Brick Red Cool 213		36.0	37.3	37.6	0.2	37.3	37.6	0.6	36.1
872R10 Brick Red Cool 214		35.8	37.4	37.5	0.2	36.8	37.6	0.5	35.7
815R71 Brick Red Std 215		18.6	29.8	19.2	0.1	30.6	19.6	0.7	29.5
Terracotta M3308	Concrete tile	29.9	12.6	30.6	2.7	12.8	30.7	2.9	13.5
Terracotta IR3308		45.4	6.3	46.7	2.0	6.3	46.9	2.8	5.7
Chocolate M3808		12.3	4.7	12.1	1.2	5.5	12.3	1.5	5.8
Chocolate IR3808		38.4	5.1	39.6	1.2	5.4	39.6	1.7	4.9
Cool IRR - A1	Asphalt Shingle	27.2	0.4	28.0	0.5	0.4	28.4	1.7	0.4
Cool IRR - A2		26.3	0.4	26.3	0.8	0.3	27.4	0.9	0.4
Std - B1		8.6	0.2	8.6	1.7	0.2	9.5	1.7	0.2
Std - B2		8.0	0.3	8.1	1.5	0.2	8.5	1.6	0.1
Cool - C1		27.3	0.4	28.5	1.7	0.5	29.8	1.8	0.5
Cool - C2		26.3	0.3	27.7	1.3	0.3	27.9	1.2	0.4
Std - D1		12.3	0.4	12.2	0.6	0.3	12.7	1.2	0.3
Std - D2		12.1	0.3	12.1	0.9	0.3	13.2	1.2	0.4
Std Premium - E1		6.8	0.2	7.0	0.4	0.3	7.6	2.1	0.4
Std Premium - E2		6.7	0.3	6.8	0.7	0.3	7.4	0.7	0.4
Cool Premium - F1		25.1	0.4	26.2	0.2	0.6	27.1	0.3	0.4
Cool Premium - F2		27.4	0.5	28.3	0.8	0.5	29.2	0.7	0.4

[1]A1,B1,C1,D1,E1,F1 are samples of asphalt shingles cut from valley of shingle

[2]A2,B2,C2,D2,E2,F2 are samples of asphalt shingles cut from tooth of shingle

[3]Premium refers to a top-of-the-line shingle having a 50 year warranty

- American Society for Testing and Materials (ASTM). 2005. Designation G 155-04a: Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Nonmetallic Materials. West Conshohocken, Pa.: American Society for Testing and Materials.

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 8/31/2005
1	**Preliminary Activities**					
1.1	Attend Kick Off Meeting *Deliverables:* • Written documentation of meeting agreements and all pertinent information (**Completed**) • Initial schedule for the Project Advisory Committee meetings (**Completed**) • Initial schedule for the Critical Project Reviews (**Completed**)	5/16/02	5/16/02	6/1/02	6/10/02	100%
1.2	Describe Synergistic Projects *Deliverables:* • A list of relevant on-going projects at LBNL and ORNL (**Completed**)	5/1/02	2/1/02	5/1/02	5/1/02	100%
1.3	Identify Required Permits	N/A		N/A		
1.4	Obtain Required Permits	N/A		N/A		
1.5	Prepare Production Readiness Plan	N/A		N/A		
2	**Technical Tasks**					
2.1	Establish the project advisory committee *Deliverables:* • Proposed Initial PAC Organization Membership List (**Completed**) • Finalize Initial PAC Organization Membership List (**Completed**) • PAC Meeting Schedule (**Completed)** • Letters of Acceptance (**Completed)**	6/1/02	5/17/02	9/1/02	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 8/31/2005
2.3	PAC meetings (**Completed)** *Deliverables:* • Draft PAC meeting agenda(s) with back-up materials for agenda items • Final PAC meeting agenda(s) with back-up materials for agenda items • Schedule of Critical Project Reviews Draft PAC Meeting Summaries • Final PAC Meeting Summaries	9/1/02	6/1/02	6/1/05		100% (6/6)
2.4	Development of cool colored coatings					
2.4.1	Identify and Characterize Pigments with High Solar Reflectance *Deliverables:* • Pigment Characterization Data Report (**Completed)**	6/1/02	6/1/02	12/1/04 → 12/31/04	12/31/04	100%
2.4.2	Develop a Computer Program for Optimal Design of Cool Coatings *Deliverables:* • 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 *Deliverables:* • 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 *Deliverables:* • 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 *Deliverables:* • Summary Coating Report **(Completed)** • 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 *Deliverables:* • Accelerated Weathering Testing Report	11/1/02	10/1/02	6/1/05 → 10/1/05		~ 80%

Project Tasks and Schedules (contd.)

Task	Task Title	Plan Start Date	Actual Start Date	Plan Finish Date	Actual Finish Date	% Completion as of 8/31/2005
2.6	Field-testing and product useful life testing					
2.6.1	Building Energy-Use Measurements at California Demonstration Sites *Deliverables:* • Demonstration Site Test Plan (**Completed)** • Test Site Report	6/1/02	9/1/02	10/1/05 → 10/1/06		92%
2.6.2	Materials Testing at Weathering Farms in California *Deliverables:* • Weathering Studies Report	6/1/02	10/1/02	10/1/05 → 10/1/06		90%
2.6.3	Steep-slope Assembly Testing at ORNL *Deliverables:* • Whole-Building Energy Model Validation • Presentation at the Pacific Coast Builders Conference • Steep Slope Assembly Test Report	6/1/02	10/1/02	10/1/05		95%
2.6.4	Product Useful Life Testing *Deliverables:* • 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)** *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	6/1/05	100%
2.7.2	Market Plan *Deliverables:* • Market Plan(s) **(Completed)**	5/1/05	4/1/05	6/1/05	7/10/05	100%
2.7.3	Title 24 Code Revisions *Deliverables:* • Document coordination with Cool Roofs Rating Council in monthly progress reports (**Completed)** • 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) *Deliverables:* • Minutes of the CPR meeting					
XII (C)	Monthly Progress Reports *Deliverables:* • Monthly Progress Reports (**Completed)**	6/1/02	6/1/02	6/1/05		109% (39/36)
XII (D)	Final Report *Deliverables:* • Final Report Outline • Final Report	3/1/05 → 3/31/06		10/1/05 → 10/1/06		
	Final Meeting *Deliverables:* • Minutes of the final meeting	10/15/05		10/31/05		