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ABSORBER COATINGS' DEGRADATION*

by

S. W. Moore

ABSTRACT

This report is intended to document some of the Los Alamos efforts that have been carried out under the Department of Energy (DOE) Active Heating and Cooling Materials Reliability, Maintainability, and Exposure Testing Program. Funding for these activities is obtained directly from DOE although they represent a variety of projects and coordination with other agencies.

Major limitations to the use of solar energy are the uncertain reliability and lifetimes of solar systems. This program is aimed at determining material operating limitations, durabilities, and failure modes such that materials improvements can be made and lifetimes can be extended. Although many active and passive materials and systems are being studied at Los Alamos, this paper will concentrate on absorber coatings and degradation of these coatings.

I. INTRODUCTION

The Los Alamos National Laboratory has been involved over the past few years in a large number of materials-related solar projects. Recently, we have developed a modeling capability to determine the potential performance benefits for various materials. This program has progressed through a validation program in which materials are tested in devices ranging from active collectors to various passive concepts.

Many advanced materials were developed during the late 1970s as a result of the National Program Plan for Research and Development in Solar Heating and

*Work performed under the auspices of the U. S. Department of Energy, Office of Solar Heat Technologies.

Cooling and the resulting solicitations. Many of the more promising of these advanced materials were carried into an evaluation program at Los Alamos.

Although these materials developments included absorbers, glazings, insulations, and sealants, this document will focus on absorber coatings and coatings degradation.

II. LOS ALAMOS TEST PROGRAMS

A. Commercial Materials Exposure Testing

Los Alamos continues to serve as one of the real-time exposure facilities for the Desert Sunshine Exposure Tests, Inc. (DSET) materials exposure testing program for commercial materials. These sites are as follows:

1. DSET - hot dry desert environment,
2. Everglades Testing Laboratory - subtropical,
3. Compton, California - industrial environment,
4. Los Alamos - high-altitude environment.

The materials, consisting of selective and nonselective absorbers, reflectors, and glazings, were all third-party procured and, at the time they were procured, were representative of the products being marketed. The materials have now undergone 2 years of exposure and the 2-year properties are being measured at DSET. These samples will be returned to the test sites for additional exposure early in 1984. Figure 1 shows the overall test facility with the commercial materials exposure samples mounted thereon.

B. Research Materials Exposure Testing

Because the DSET program is focused entirely on commercially available materials, there is a need to evaluate research and developmental materials that might prove to be cost effective. Los Alamos has attempted to fill a portion of this void by obtaining and testing some of the more promising advanced materials. The initial selective absorber materials chosen for evaluation are shown in the following table:

TABLE I

ADVANCED SELECTIVE COATINGS

Nickel-pigmented anodic Al_2O_3 on aluminum.

Cr-CrO_2 composite film on aluminum.

Colored stainless steel.

Chemical conversion coatings on aluminum.

Chemical conversion coatings on copper and brass.

Chemical conversion coatings on nickel.

Chemical conversion coatings on zinc or zinc/aluminum.

Chemical conversion coatings on stainless steel.

SnO_2 coating on porcelain enamel.

Thickness-sensitive selective paints.

Thickness-insensitive selective paints.

Most of these materials have now been subjected to stagnation exposure testing for 2 years.

Outdoor stagnation testing of collector absorber materials was also carried out at the Los Alamos exposure facility shown in Fig. 1. Five exposure boxes based on the American Society for Testing Materials (ASTM) E781-81 standard were constructed to provide a range of conditions as follows:

Box No.	Identification Code	Description
1	OPEN	Unglazed, flat black absorber; no insulation between absorber plate and back of box.
2	SGFB	Single glazed, flat black absorber; insulated.
3	DGFB	Double glazed, flat black absorber; insulated.
4	SFGSS	Single Tedlar-film glazed, selective absorber; no insulation between absorber plate and back of box.
5	SGSS	Single glazed, selective absorber; insulated.

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Fig. 1. Los Alamos exposure facility.

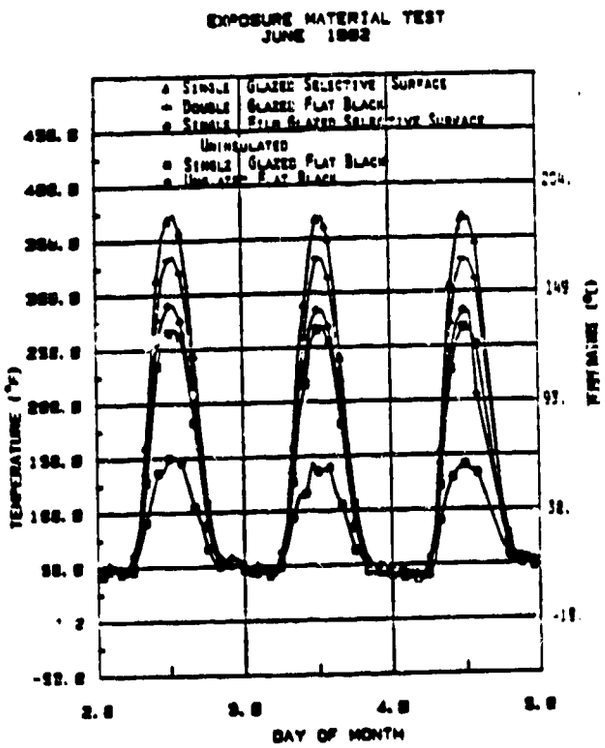

Fig. 2. Exposure box temperatures.

Typical daily variations in exposure-box temperatures are shown in Fig. 2. Under these exposure conditions, the maximum temperatures vary from 150 to 375°F. Other time periods have produced higher exposure temperatures. A small deviation in sample temperatures can be expected because of the differences in sample optical properties as compared with the sample-mounting-plate properties.

In applicable cases both the front-side and back-side properties of exposure samples were measured, providing an indication of daily temperature cycling only or daily temperature cycling with ultraviolet exposure. If any photochemical reaction mechanisms occur, the front/back measurements could indicate this effect.

Table I describes the types of selective absorber coatings being evaluated at Los Alamos. These are coatings that had not reached full commercialization in the U. S. at the time they were selected for evaluation.

An example of the type of data being taken and the results are shown in Table II. This is only a partial list of the selective paints undergoing exposure testing, but should be representative of the types of results being obtained. Initial results of the program are covered in Los Alamos report LA-9735-MS. The update of this program will be completed in the near future.

As can be seen in Table II, the results vary from no change in optical properties to decreases in α_s or increases in ϵ, either of which constitute a performance decrease. Some coatings have even shown stable α_s with a decrease in ϵ, which constitutes a performance improvement over the time tested. One must be cautious with any changing property, however, because measurements could show a peak or a reversal and subsequently undergo changes indicating a degradation in property values.

III. FULL-SIZED COLLECTOR INVESTIGATIONS

Two examples of the many full-sized collector absorbers which have been evaluated follow below.

A. Black Chrome Selective Absorbers

Table III shows that only insignificant change has occurred to black chrome collectors after 5 years of stagnation testing at Los Alamos.

TABLE II

SELECTIVE PAINTS

Paint	Process	Substrate	Exposure Box/Side	Original α_s/ϵ	3-Month Exposure α_s/ϵ	6-Month Exposure α_s/ϵ	12-Month Exposure α_s/ϵ
Honeywell TSSP	Dip-coated w/FEP overcoat	Aluminum sheet	5/F	0.930/0.178	---	0.929/0.168	0.923/0.167
			5/R	0.930/0.155	---	0.928/0.151	0.924/0.150
Honeywell TSSP	Reverse-roll-coat production simulation	Aluminum foil	1/F	0.867/0.104	0.857/0.144	0.859/0.145	0.860/0.130
			4/F	0.862/0.108	0.865/0.139	0.866/0.147	0.857/0.139
			5/F	0.875/0.110	0.880/0.100	0.877/0.131	0.875/0.135
Honeywell rotogravure print w/SR-125 resin	Preproduction run	Aluminum foil	1/F	0.924/0.230	0.920/0.267	0.922/0.280	0.924/0.268
			4/F	0.919/0.245	0.925/0.276	0.925/0.259	0.922/0.249
			5/F	0.922/0.236	0.927/0.245	0.929/0.251	0.923/0.262
Honeywell rotogravure print w/6247 resin	Preproduction run	Aluminum foil	1/F	0.915/0.284	0.913/0.294	0.933/0.246	0.924/0.243
			4/F	0.917/0.323	0.913/0.366	0.928/0.314	0.924/0.296
			5/F	0.918/0.310	0.926/0.264	0.930/0.242	0.930/0.257
Honeywell rotogravure print w/SR-125 resin	Production simulation	Aluminum foil	1/F	0.889/0.092	0.891/0.097	0.894/0.090	0.892/0.102
			2/F	0.890/0.093	0.888/0.094	0.887/0.093	0.886/0.091
			3/F	0.883/0.076	0.883/0.083	0.881/0.068	0.878/0.071
			4/F	0.894/0.090	0.893/0.090	---	0.888/0.088
			5/F	0.888/0.102	0.894/0.094	---	0.888/0.084
Honeywell rotogravure print w/6247 resin	Production simulation	Aluminum foil	1/F	0.897/0.134	0.875/0.083	0.825/0.072	0.764/0.076
			2/F	0.899/0.144	0.898/0.113	0.896/0.107	0.893/0.102
			3/F	0.898/0.140	0.900/0.100	0.898/0.096	0.897/0.093
			4/F	0.900/0.143	0.905/0.103	---	0.898/0.087
			5/F	0.902/0.142	0.902/0.086	---	0.899/0.079
Los Alamos-applied Honeywell TISP on Al	Light coat	Aluminum sheet	5/F	0.865/0.166	0.851/0.162	0.843/0.166	0.839/0.166
	Med. coat		5/F	0.890/0.262	0.882/0.267	0.876/0.260	0.874/0.267
	Heavy coat		5/F	0.874/0.253	0.863/0.252	0.859/0.252	0.858/0.254
Los Alamos-applied Honeywell TISP on primed steel	Light coat	1010 mild steel (primed)	5/F	0.908/0.679	0.907/0.681	0.905/0.692	0.904/0.688
	Med. coat		5/F	0.902/0.473	0.898/0.476	0.895/0.478	0.895/0.473
	Heavy coat		5/F	0.881/0.392	0.874/0.404	0.875/0.393	0.868/0.397
Los Alamos-spray-applied Thermo-250 on stainless steel	Bare	347 stainless steel	5/F	0.472/0.142	0.482/0.137	0.495/0.143	0.500/0.146
	Light spray		5/F	0.865/0.543	0.871/0.537	0.871/0.537	0.874/0.533
	Heavy spray		5/F	0.871/0.810	0.872/0.806	0.872/0.813	0.873/0.810
Los Alamos-spray-applied Thermo-250 on aluminum	Bare	Aluminum sheet	5/F	0.074/0.030	0.077/0.029	0.081/0.032	0.070/0.031
	Light		5/F	0.800/0.490	0.810/0.483	0.800/0.483	0.809/0.475
	Heavy		5/F	0.868/0.790	0.872/0.793	0.871/0.789	0.869/0.790
Los Alamos-spray-applied Dulite (a)	Bare	Aluminum sheet	5/R	---	0.072/0.045	0.076/0.034	0.070/0.035
	Heavy-5 spray passes		5/F	0.954/0.867	0.949/0.850	0.953/0.845	0.949/0.843
	Medium-3 passes		5/F	0.957/0.844	0.950/0.832	0.957/0.826	0.950/0.825
	Light-1 pass		5/F	0.939/0.796	0.917/0.785	0.922/0.782	0.903/0.782

(a) Better properties could probably have been obtained with greater optimization and better process control; however, these samples were used to determine changes that may have been occurring. Dip-coated samples produced α_s/ϵ of 0.950/0.894.

TABLE III

BLALX CHROME COLLECTOR RESULTS

5-Year Stagnation

Los Alamos, New Mexico

Original Properties		Poststagnation Properties		Change in Properties	
α_s	ϵ	α_s	ϵ	$\Delta\alpha_s$	$\Delta\epsilon$
0.922	0.102	0.931	0.113	+0.009	+0.011
0.942	0.108	0.933	0.103	-0.009	-0.005
0.933	0.120	0.930	0.120	-0.003	0.000
0.922	0.088	0.929	0.098	+0.007	+0.010
0.929	0.098	0.925	0.086	-0.004	-0.012
0.940	0.117	0.940	0.125	0.000	+0.008
0.940	0.114	0.943	0.107	+0.003	-0.007
0.924	0.114	0.930	0.110	+0.006	-0.004
Average Properties					
0.931	0.108	0.933	0.108	+0.002	0.000

TABLE IV

MIROMIT COLLECTOR

Collector Visual Sample Description	α_s (a)	ϵ (b)
Blue-purple	0.834	0.093
Pinkish-brown	0.848	0.090
Golden-yellow	0.836	0.087
Whitish deposit region	-----	0.180

(a) We determined α_s using a Beckman-5270 Spectrophotometer with integrating sphere and integration of the SERI 100-point air mass 1.5 solar data (similar to 80-point ASTM E891-82).

(b) We determined ϵ by using a Gier Dunkle DB-100 Infrared Reflectometer.

B. Perl-Mac/Miromit Black Nickel Study

Samples taken from a Miromit collector used on the Perl-Mac Demonstration Housing Project, Denver, Colorado, have been analyzed for optical property degradation. This collector had undergone approximately 2 years of combined stagnation and normal operation before removal for evaluation. Optical results obtained from the various areas of the collector are shown in Table IV.

Although there is a significant visual color change in the samples, there is little difference among the integrated absorptances. The spectral reflectance curves show that large changes in the visible portion of the solar spectrum can be offset by changes in the near infrared, while maintaining a nearly constant α_s. This is a good example of how the eye is a poor tool in determining full solar-spectrum optical properties. Some people have mistakenly painted the yellow areas with black paint in an attempt to improve performance. A small area on the collector where a whitish crystalline zinc salt has formed exhibited seriously impaired emittance properties.

RECOMMENDATIONS

- Develop more cost-effective systems and materials through lower production costs, greater performance, and improved durability.
- Develop organizations and coordinating groups to establish and maintain quality standards.
- Improved communication between industry and researchers.
- Place greater emphasis on materials for use in passive solar applications.

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