An Evaluation of Acrylic Coated 55% Al-Zn Alloy Coated Sheet Steel Roofing Material to Determine Whether it Meets the Requirements of the EPA Energy Star® Program for Reflective Roofing Materials

Prepared for

Galvalume Sheet Producers of North America

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Introduction

As part of a research project to assess the long-term durability and energy efficiency of their metal roofing products, the Galvalume Sheet Producers of North America have teamed with the Oak Ridge National Laboratory to determine whether acrylic coated 55% Al-Zn alloy coated sheet steel roofing meets the requirements of the EPA Energy Star® Program for reflective roofing materials. To meet the requirements for low-slope roofing, the EPA Energy Star® Program (see Appendix A) requires that a roofing material must have an initial reflectance greater than or equal to 0.65 and must maintain a reflectance greater than or equal to 0.50 after three years weathering on a roof. In contrast, the reflectance requirements for high-slope roofing are less stringent in that the initial reflectance must be greater than or equal to 0.25 and the reflectance, after three years weathering on roofs, must be maintained at a value greater than or equal to 0.15. However, the Energy Star Program specifies that roof materials used for both high-slope and low-slope roof applications must meet the more stringent low-slope requirements.

The EPA program allows two methods for determining the initial solar reflectance of new roofing materials, ASTM E 903 Standard Test Method for "Solar Absorptance, Reflectance, and Transmission of Materials Using Integrating Spheres" or a reflectometer similar to the one manufactured by Devices and Services Company. For the solar reflectance measurements on aged roofing materials, the EPA program allows the reflectometer method mentioned above and ASTM E1918 Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field. For this effort, the reflectometer method was used, employing a Devices and Services Company Solar Spectrum Reflectometer. The reflectometer in position on a roof, is shown in Figure 1.

Figure 1 Devices and Services Company reflectometer

The reflectometer was used for both the new and in-situ samples. The established procedures for proper and repeatable operation of the Devices and Services Company reflectometer were established at the Oak Ridge National Laboratory and appear in Appendix B.

Product Specifications and Trademarks

55% Al-Zn alloy coated sheet steel is manufactured under license by BIEC International Inc. in conformance with ASTM Specification A792/A792M-97a, Standard Specification for "Sheet Steel, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process." It is manufactured and sold under the trademark GALVALUME® by Bethlehem Steel Corporation, Dofasco Inc., National Steel Corporation, U. S. Steel Group of USX Corporation, and Wheeling-Nisshin, Inc. It is also manufactured and sold by BHP Coated Steel Corporation under its registered trademark ZINCALUME®, by Industrias Monterrey S. A. under its trademark ZINTRO-ALUM™ and by GALVAK, S. A. de C. V. under its trademark GALVAL™. (GALVALUME® is an internationally recognized and registered trademark of BIEC International Inc. and some of its licensed producers, and a trademark of Dofasco Inc. of Canada).

55% Al-Zn alloy coated sheet is sold with either a special chemical treatment or a very thin acrylic coating to protect it during shipment and storage. Reflectance measurements for the chemically treated sheet are reported in the ORNL Report, "An Evaluation of Chemically Treated 55% Al-Zn Alloy Coated Sheet Steel Roofing Material to Determine Whether it Meets the Requirements of the EPA Energy Star® Program for Reflective Roofing Materials". This report covers solar reflectance measurements for acrylic coated sheet. Manufacturers sell this product under modified trademarks to distinguish it from chemically treated sheet. Bethlehem Steel Corporation, Dofasco Inc., National Steel Corporation and Wheeling-Nisshin, Inc. manufacture and sell it under the GALVALUME® PLUS trademark. It is also manufactured and sold under the trademarks ACRYLUME® by U.S. Steel Group of USX Corporation, ZINCALUME® PLUS by BHP Coated Steel Corporation and ZINTRO-ALUM™ PLUS by Industrias Monterrey S.A. (ACRYLUME® is a registered trademark of U.S. Steel Group of USX Corporation.)

Procedure

The test methods for the EPA Energy Star® Roof Products Program, Appendix A, state the procedures allowed to determine if a material meets the minimum qualifications necessary for the EPA Energy Star® Label. To test whether new materials meet the initial reflectance requirements, reflectance measurements must be made on newly manufactured and unexposed samples using equipment and procedures specified in the standard. Similarly, to determine whether roof materials maintain the required reflectance after weathering, the reflectance must be measured on three roofs made with the subject roof material. These roof membranes must be at least three years old, with at least one such roof being located in a major metropolitan area.

The Galvalume Sheet Producers of North America asked Oak Ridge National Laboratory (ORNL) to determine the initial and weathered reflectance of their acrylic coated 55% Al-Zn coated sheet steel. ORNL has the required equipment and skilled personnel to measure the solar reflectance of materials in the laboratory and of roofs in the field. ORNL is also actively engaged in projects to study the influence of roof solar reflectance on inside building cooling and heating energy requirements.

Initial Solar Reflectance

The initial solar reflectance of acrylic coated 55% Al-Zn coated sheet steel was determined on newly manufactured and unexposed samples submitted by seven member companies of the Galvalume Sheet Producers of North America. Table 1 lists the companies, in alphabetical order, submitting samples and the number of samples received from each.

Company Name	No. of Samples
Bethlehem Steel	3
BHP Coated Steel Corp.	3
Dofasco, Inc. (Canada)	3
IMSA (Industrias Monterrey, S.A.) (Mexico)	3
National Steel Corp.	1
U.S. Steel	3
Wheeling-Nisshin	3

Table 1 Companies supplying newly manufactured samples of acrylic coated 55% Al-Zn alloy coated sheet steel for initial solar reflectance measurements

It should be noted that all companies listed are members of the Galvalume Sheet Producers of North America and each of these companies produce 55% Al-Zn alloy coated sheet steel under license of BIEC International Inc.

To maintain anonymity, the companies will hereafter be referred to as companies A-G and in a random order determined by the order in which the samples were selected for measurement.

As shown in Table 1, all manufacturers except National Steel provided three samples of the acrylic coated 55% Al-Zn alloy coated sheet steel material. The average initial solar reflectance of each manufacturer's samples and the overall average initial solar reflectance of all samples are presented in Table 2.

Manufacturer Code	Initial Solar Reflectance
A	0.71
B	0.67
C	0.67
D	0.67
E	0.67
F	0.68
G	0.70
Overall Average	0.68

Table 2 Initial reflectance of acrylic coated 55% Al-Zn alloy coated sheet steel

For the single sample, a minimum of three measurements were made and the average of those readings is the reported reflectance. Where multiple samples were provided, a minimum of three measurements were made on each sample and the average of all readings is the reported reflectance of the samples from each manufacturer. Finally, the overall average represents the initial solar reflectance of the entire collection of samples provided by all manufacturers.

Note that the overall average initial reflectance of samples from all producers is above the EPA minimum requirement of 0.65. Also, the initial solar reflectance of samples from each individual manufacturer shows good correlation with samples from the other manufacturers, indicating that the reflectance of the product is consistent from producer to producer.

Maintenance of Solar Reflectance

To meet the Energy Star requirements for maintenance of solar reflectivity, reflectance measurements were made on three acrylic coated 55% Al-Zn alloy coated sheet roofs over three years old and located in three different areas of the country. Roof panel manufacturers verified the ages of the roofs, which ranged from three years and two months to three years and four months at the time the measurements were made. The subject roofs were Eufaula Self Storage, Eufaula, AL, Williams Gas, Ottawa, KS, and Croson-Teepe Mechanical Contractors, Columbus, OH. The self storage facility in Eufaula was actually two separate buildings. While data are shown individually for each building, the facility will be treated as one building and the overall reflectance at this site will be the average of both buildings. Pictures of the subject roofs appear in Figures 2 through 4.

Figure 2 Eufaula Self Storage

Figure 3 Williams Gas

Figure 4 Croson-Teepe Mechanical Contractors

The roofs were divided into ten equal sections and reflectance measurements were then made in the approximate center of each section. At least three measurements were made in each of the ten sections. The average of all measurements from the ten individual sections of each roof was reported as the overall solar reflectance of that roof.

Sampling locations within the center of the ten equal areas were selected at random to achieve a representative sampling of the entire roof. Figure 5 shows a close-up of a typical section of acrylic coated Al-Zn alloy coated sheet steel roofing.

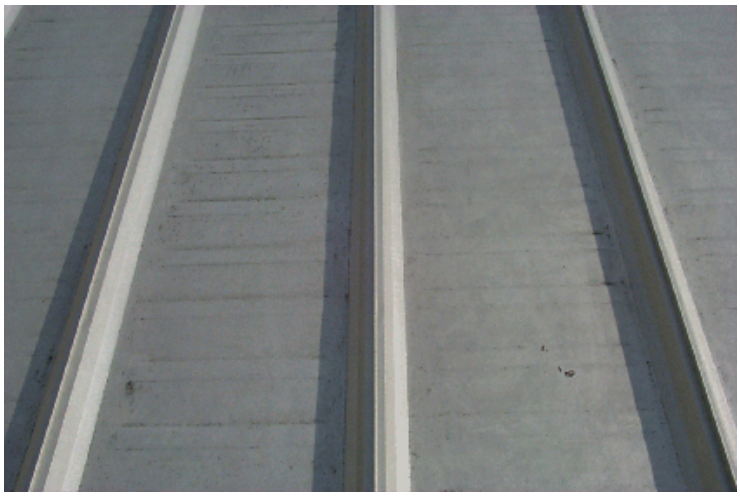

Figure 5 Close-up of a typical acrylic coated 55% Al-Zn alloy coated sheet weathered roof

The average of all reflectance measurements made in each of the ten designated areas, as well as the overall averages for each roof are presented in Table 3.

	Self-Storage (AL)			
Location	Bldg. 1	Bldg. 2	Williams Gas (KS)	Croson-Teepe (OH)
1	0.53	0.59	0.54	0.57
2	0.53	0.58	0.51	0.55
3	0.56	0.56	0.51	0.54
4	0.55	0.64	0.49	0.55
5	0.56	0.60	0.51	0.58
6	0.58	0.59	0.50	0.57
7	0.55	0.56	0.51	0.56
8	0.57	0.57	0.51	0.58
9	0.54	0.57	0.53	0.58
10	0.53	0.58	0.55	0.57
Overall average	0.57		0.52	0.56

Table 3 Weathered solar reflectance values of non-cleaned surfaces on three acrylic coated 55% Al-Zn alloy coated sheet steel roofs

Although the EPA standard allows cleaning of the roofs according to the manufacturer's recommended maintenance procedures before measuring the reflectance, all reflectance values shown in Table 3 are for non-cleaned surfaces.

Note that the overall average reflectance of each of the three roofs exceeds the minimum EPA requirement for maintenance of solar reflectance of 0.50.

Conclusions

The test methods for the Energy Star® Roof Products Program were followed for the measurement of both initial solar reflectance and maintenance of solar reflectance on acrylic coated 55% Al-Zn alloy coated sheet steel roofing materials.

The overall average initial solar reflectance of all newly manufactured acrylic coated 55% Al-Zn alloy coated sheet samples, from seven member companies of the Galvalume Sheet Producers of North America, was 0.68. This value exceeds the minimum EPA Energy Star® requirement of 0.65 for new materials. Similarly, the overall average reflectance of three non-cleaned weathered

roofs, over three years old in the Eufaula, AL, Ottawa, KS, and Columbus, OH areas, was 0.57, 0.52, and 0.56, all of which exceed the EPA requirement of 0.50 for maintenance of solar reflectivity.

On the basis of these measurements and the requirements of the Energy Star® Roof Products Program, acrylic coated 55% Al-Zn alloy coated sheet qualifies as an Energy Star roof material and according to the rules detailed in the EPA's Memorandum of Understanding can be promoted as such for both low-slope and high-slope roof applications.

APPENDIX A

Test Methods for Energy Star® Roof Products Program

D. Product Qualification for the EPA ENERGY STAR Label

ENERGY STAR Partner agrees that only those roof products that meet the specifications listed in either Table 1 or Table 2, below, may qualify as ENERGY STAR-compliant. **For roof products that may be applied to either low-slope or steep-slope roofs, such as roof coatings and single-ply membranes, Table 1 contains the applicable ENERGY STAR specifications.**

Table 1 - Low-Slope Roofs.

Specifications	
Characteristic	**Performance Specification**
Energy Efficiency	
Initial Solar Reflectance	Greater than or equal to 0.65.
Maintenance of Solar Reflectance	Greater than or equal to 0.50 three years after installation under normal conditions.
Reliability	
Manufacturer warranty for defects in materials and manufacturing	Each company's warranty for reflective roof products must be equal in all material respects to the product warranty offered by the same company for comparable non-reflective roof products. A company that sells only reflective roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-reflective roof products.

Table 2 - Steep-Slope Roofs.

Specifications	
Characteristic	**Performance Specification**
Energy Efficiency	
Initial Solar Reflectance	Greater than or equal to 0.25.
Maintenance of Solar Reflectance	Greater than or equal to 0.15 three years after installation under normal conditions.
Reliability	
Manufacturer warranty for defects in materials and manufacturing	Each company's roof product warranty for reflective roof products must be equal in all material respects to the product warranty offered by the same company for comparable non-reflective roof membrane products. A company that sells only reflective roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-reflective roof products.

ATTACHMENT C
Test Methods for ENERGY STAR® Roof Products Program

Meeting the Specifications

To meet the specification, the roof product must be tested under the following conditions using the test methods listed. All performance measurements must be completed as described herein, and all the results must comply with the requirements stated in the MOU.

Energy Efficiency Measurements

Initial Solar Reflectance

Product shall be tested using ASTM E 903 - Standard Test Method for Solar Absorptance, Reflectance, and Transmission of Materials Using Integrating Spheres. Products need only be tested for solar reflectance (values for solar absorptance and transmission need not be obtained). Manufacturers will submit a 3" X 3" flat sample of each product to a laboratory that has the appropriate equipment. The manufacturer shall request that the test be performed using a black background for the sample. Where appropriate, the sample shall be prepared according to manufacturer recommendation for thickness used in the field.

Partner may also employ a reflectometer such as the one produced by Devices and Services Company. Partner shall follow the procedures outlined in Attachment D provided by Oak Ridge National Laboratories.

If manufacturer has performed the test for initial solar reflectance on a particular product since 1996, the product need not be retested. The manufacturer must have a record of the test results on file. Particularly with regard to roof coatings, if partner has changed a fundamental element of product formulation such as the base latex, partner must retest for the initial solar reflectance of the product. In addition, to ensure other product formulation changes will not affect the solar reflectance of the product, Partner shall certify that the product formulation or recipe has not changed since the solar reflectance testing was performed.

Maintenance of Solar Reflectance

Partner shall identify three existing roofs on which the same product was installed a minimum of three years prior. At least one of these existing roofs must be located within a major metropolitan area such as Atlanta, Boston, Chicago, Dallas, Houston, Los Angeles, Miami, Minneapolis, New York, Philadelphia, San Francisco, St. Louis, Washington D.C., etc. The roof product need not have been installed at the same time on the three buildings however, the roofs must each be at least three years old. Roofs that are chosen may be cleaned according to proper maintenance procedures as recommended by the manufacturer before tests are performed.

For low-slope roof products and coatings, Partner shall use either ASTM E1918 - Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field or

the Solar Spectrum Reflectometer Test outlined in Attachment D, to test the solar reflectance of the roof product as installed and weathered for three years. Partner shall divide the roof into at least 10 equal sections. Measurements shall be performed in the center of each area. At least three repetitions shall be made of each measurement. Partner shall take the average of all solar reflectance values obtained from the roof to determine if the solar reflectance of the roof product as installed and weathered for three years is greater than or equal to the stated threshold value (0.50). If Partner is employing ASTM E1918, the test must be performed on a clear day (no clouds)between 10:00 AM and 2:00 PM when the sun is high in the sky and there can be no obstruction in the field of view.

To measure the solar reflectance of steep-slope roofs as installed and weathered for three years, Partner shall employ a reflectometer such as the one produced by Devices and Services and shall follow the procedures outlined in Attachment D. Partner shall divide the roof into at least 10 equal sections. Measurements shall be performed in the center of each area. At least three repetitions shall be made of each measurement. Partner shall take the average of all solar reflectance values obtained from the roof to determine if the solar reflectance of the roof product as installed and weathered for three years is greater than or equal to the stated threshold value (0.15 for products that can only be applied on steep-slope roofs; 0.50 for products that can be applied to either low-slope or steep-slope roofs).

Alternatively, Partner may test for solar reflectance of the product after three years by taking samples from the existing roofs as identified above, and having those samples tested according to ASTM E 903 as described above. Subsequently, the Partner is responsible for ensuring that the roof from which samples were taken is properly repaired so as to resume watertight integrity.

APPENDIX B

Devices and Services Company Reflectometer Procedures

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DEVICES & SERVICES COMPANY SOLAR SPECTRUM REFLECTOMETER, VERSION 5.0

1. Instrument

1.1 The Devices & Services Company Solar Spectrum Reflectometer, Version 5.0 is designed to provide a measurement of solar reflectance for laboratory and in-situ samples of flat, first-surface reflectors. Accessories and techniques are suggested in the operator's manual for curved and second-surface reflectors.

1.2 The instrument consists of three parts: a measurement head; a control and readout module; and, up to 7.6 m (25 ft) of connecting cable. The control and readout module contains a keypad to select the various options for operation. An opening in the measurement head is placed directly against a flat sample. Up, down or sideways orientation is permitted. The sample is illuminated diffusely with a tungsten halogen lamp for two seconds out of a ten second measurement cycle. Reflected light is measured at an angle of 20° from the incident angle with four separate detectors. Each detector is equipped with color filters to tailor its response to a range of wavelengths in the solar spectrum.

1.3 Software in the instrument combines the outputs of the four detectors in appropriate proportions to approximate the response over the solar spectrum for incident solar radiation through air mass 0, 1, 1.5 or 2. The solar reflectance for the desired air mass is selectable by pressing and holding a key on the instrument's keypad until the desired air mass cycles to the display. The solar reflectances measured by the four individual detectors are also available with this key on the keypad. The output is updated every ten seconds and will continue to be the solar reflectance for the last selection until a new selection is made. The output of the instrument is the selected solar reflectance as a fraction between 0 and 1. The resolution of the digital readout is 0.001.

2. Test Samples and Sampling Area

2.1 The opening on the measurement head is 2.5 cm (1 in.) in diameter. Reflectances can be obtained for this area on a sample within 30 seconds by placing the measurement head over the desired area and allowing at least three cycles to check that a stable reading has been obtained. Several areas should be sampled to obtain data from which an average over the desired sample area can be calculated. The values for each area are best recorded manually on a data sheet with notes about the location and appearance of the sampling area.

3. Operating Procedures

3.1 The instrument requires 110 volt AC power but can be used outdoors if conditions are dry. Before power is applied and the instrument is turned on, either end of the cable must be connected to the socket on the measurement head. The other end must be connected to the socket on the readout and control module. The instrument powers up ready to measure total solar reflectance through air mass 2. Normal operation is to obtain solar reflectance over the total solar spectrum through air mass 2. Normal operating procedure requires a warm up period of about 30 minutes. The instrument can be left on for extended periods of time with a cover over the measurement head opening.

3.2 At the end of the warm up period, zero and gain should be checked and adjusted if necessary. A zero reflectance, blackbody cavity and various high reflectance standard samples are provided to check zero and

gain. If the blackbody cavity covers the opening of the measurement head and a non-zero reading is noted, the calibration/zero key should be depressed. The instrument detects the presence of the zero reflectance cavity and resets the output reflectance to zero.

3.3 The gain or calibration adjustment requires that the reflectance of a known standard be coded into the instrument. Three standards provided with the instrument are preprogrammed into the memory. Five additional standards can be programmed by the user. A selection key on the keypad allows the user to select which of eight standards will be used. If the desired standard covers the opening of the measurement head and its reflectance is not noted on the display, the calibration/zero key should be depressed. When a calibration standard is over the measurement head opening and the calibration/zero key is depressed, the instrument automatically detects that a high reflectance object is in place and resets the output reflectance to the selected standard's preset value.

3.4 Zero is very stable but is conveniently checked by using the blackbody cavity as a way to cap the measurement head between samples. Gain is fairly stable but checking the gain should be done once every 30 minutes after warmup and the gain or calibration adjustment procedure of paragraph 3.3 repeated if necessary.

4. Calculations

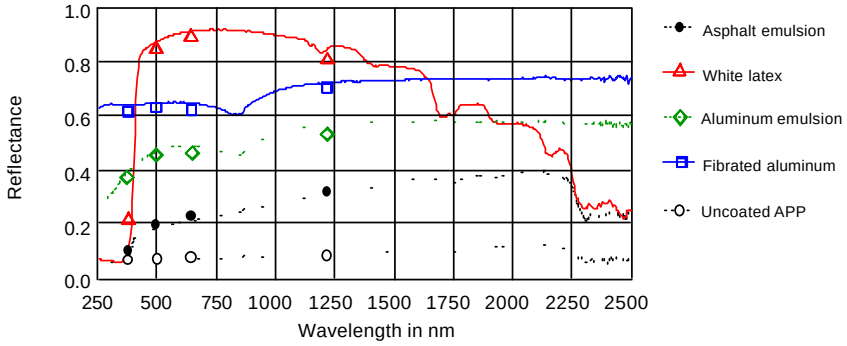
4.1 With a set of reflectance values available for the desired areas of a sample, the arithmetic average of the values is most conveniently found with a calculator or in a spreadsheet. A calculator or spreadsheet allows the standard deviation to be found for the average. The standard deviation indicates the scatter about the average. Typical scatter from different locations that appear equally bright on the same sample is ±0.003 to ±0.01.

5. Precision and Bias

5.1 Drift of no more than ±0.003 from the calibration value is typical during 30 minutes of operation after warmup and setting of the gain. Therefore the instrument's precision is ±0.003 but the precision of the average of several measurements is usually governed by the variability of reflectances from area to area on a sample.

5.2 In a collaborative effort to document the bias of the Devices & Services (D&S) Solar Spectrum Reflectometer, Oak Ridge National Laboratory (ORNL) and Lawrence Berkeley National Laboratory (LBNL) compared solar spectrum reflectances of five samples including an uncoated modified bitumen and pieces of the modified bitumen coated with an asphalt emulsion, an aluminum emulsion, a fibrated aluminum and a white latex coating. These samples covered the range from poorly reflecting to highly reflecting surfaces typical for uncoated and coated low-slope roofs. LBNL measured the spectrum of reflectances from 250 to 2500 nanometers as well as the solar spectrum average for the samples using a Perkin-Elmer Lambda 19 Spectrophotometer. ORNL measured the air mass 2 solar spectrum reflectance with the D&S instrument before and after the samples were at LBNL. ORNL also recorded the output of the four individual detectors of the D&S instrument and assigned these values to the wavelength at which each detector was most sensitive.

5.3 The figure shows the continuous lines from the LBNL spectral scans and symbols from the ORNL readings with the four detectors of the D&S instrument. The individual detectors are able to provide some spectral resolution but not enough to detect differences in behavior of the test surfaces at the long wavelengths.



5.4 The table shows total solar spectrum reflectances for all the samples in the collaborative effort. The average was taken of the ORNL readings before and after the LBNL solar average was determined from the spectra for each sample. The LBNL measurements were made according to ASTM Designation: E 903-96 "Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres." ASTM E 903 states that the precision of the method (as indicated by the repeatability of measurements by the method) is typically ±0.005. Bias is not able to be specified because it depends on the individual apparatus and care with which the measurement is done. For this collaborative effort, the LBNL measurements are accepted as the true measure of the reflectance of each sample. The difference between the ORNL and LBNL averages is given for each sample in the last column of the table. The average difference of +0.003 is within the expected drift of the D&S instrument during 30 minutes of operation after warmup. The difference of +0.02 for the white latex and -0.02 for the aluminum emulsion is interpreted to mean that ±0.02 is a conservative estimate of the bias in the measurement of the solar reflectance of an individual sample with the Devices and Services Company Solar Spectrum Reflectometer, Version 5.0.

Sample description	ORNL before	LBNL Solar Avg.	ORNL after	Difference
Asphalt emulsion	0.259	0.2394	0.246	+0.013
White latex	0.844	0.8224	0.842	+0.021
Aluminum emulsion	0.472	0.4930	0.478	-0.018
Fibrated aluminum	0.659	0.6574	0.650	-0.003
Uncoated APP	0.077	0.0757	0.076	+0.001
			AVERAGE:	+0.003