EXPOSURE TESTING OF PAINTED PVDF METAL ROOFING

Reflectance and emittance data for premium coil coated metal roof products were obtained from participants of the Cool Metal Roofing Coalition and analyzed to show whether metal roofing has superior retained reflectance compared to other roofing products. Based upon work by Oak Ridge National Laboratory, pre-painted metal roofing retains 95% of its initial solar reflectance over a three-year period (Fig. 1). In comparison, similar fence post exposure studies (Fig. 2) conducted by participants of the Coalition showed that polyvinylidene fluoride (PVDF) base paint metals maintain their resistance to soiling for at least thirty years.

Data from the Coalition coincides with the data from ORNL, showing that emittance increases slightly with time but is not affected by the difference in the hot moist climate for Miami Florida to the cold and humid climate of Novia Scotia.

ORNL Three-Year Study

The solar reflectance and the infrared emittance are important surface properties affecting a roof's temperature, which in turn drives the heat flow through the roof. The solar reflectance gages the percentage of the sun's energy that a roof deflects off the building, and the infrared emittance controls the release of radiant energy from a roof. Reflectance and emittance are expressed as mathematical ratios. The reflectance (ρ) determines the fraction of radiation incident from all directions that is diffusely reflected by the surface. The emittance (ε) describes how well the surface radiates energy away from itself as compared to a blackbody operating at the same temperature. Increasing either reflectance and or emittance lowers a roof's surface temperature, which in turn decreases the summertime heat penetrating into the conditioned space.

Reflectivity measurements were made quarterly at ORNL on steep- and low-slope metal roofs (Fig. 3). After 3½ years of exposure, the white and bronze painted PVDF metal roofs, R64E83[1] and R07E87[1] respectively, have lost less than 5% of their original reflectance.

Testing conducted at the roof slopes of 4-in of rise per 12-in of run (i.e., Steep Slope Roof [SSR] in Fig. 3) and at ¼-in of rise per 12-in of run (i.e., Low Slope Roof [LSR] in Fig. 3) further show that the slope of the roof has little effect on the loss of reflectance. The painted metal appears to have excellent corrosion resistance. Their surface opacity have limited any photochemical degradation caused by ultraviolet light present in sunlight over the 3-years of testing. All painted metal roofs have maintained their original manufactured appearance. After 3½ years of exposure, rains with a measured ph of 4.3 in East Tennessee (National Atmospheric Deposition Program) have not etched the metal finish. ORNL scientists detected evidence of biological growth on some of the test roofs (Miller et al. 2002); however, the PVDF surface finish does not appear to allow the growth to attach, keeping the surface clean.

[1] Each metal roof is described generically using an R*xx*E*yy* designation. R*xx* states the solar reflectance of a new sample, 1.0 being a perfect reflector. E*yy* defines the infrared emittance of the new sample, 1.0 being blackbody radiation. For example, the asphalt-shingle roof is labeled R09E91. Its freshly manufactured surface properties are therefore 0.09-reflectance and 0.91-emittance.

Most dramatic are the trends observed in the solar reflectance and the infrared emittance of the painted metal roofs tested at different exposure sites across the country. Similar reflectance was measured in the hot, moist climate of Florida as compared to the predominantly cold climate of Nova Scotia (Figure 4). The Environmental Protection Agency's Energy Star® Program requires field testing at three different building sites; however, the results for painted metal show the reflectance to be very similar whether exposed in Florida, Nova Scotia or Pennsylvania. Also solar reflectance and infrared emittance measures collected from the test fence exposure sites in Florida, Nova Scotia, Pennsylvania and also at Oak Ridge (Figure 4) are very similar to the reflectance and emittance measures recorded for the test roofs exposed on the ESRA in Oak Ridge (Figure 4). For this 3½ year time limited study, the changes in solar reflectance and infrared emittance of the painted PVDF metals is independent of climate! The results show that fence exposure data are a viable alternative for certifiying the painted PVDF metal roofs as Energy Star compliant, because they yielded very similar trends as the identical roofs exposed on the ESRA.

The emittance of the painted metal roofs did not change much after 3½ years of weathering. In fact, the data in Figure 4 shows that the emittance increased slightly over time.

Cool Metal Roofing Coalition Reflectance and Emittance Study

In order to form a broader picture of the effects of climatic soiling over the long term, Akzo Nobel, BASF, Atofina and Solvay Solexis provided exposure data of their painted metal products weathered in Miami Florida. Premium coil coated metals with ten, fifteen, and over thirty years of exposure were analyzed for the effects of soiling. All roof samples reported are 70% PVDF base paint metal systems.

Measurement Techniques

Solar reflectance and infrared emittance measurements were made using the ASTM protocols C1549 and C1371, respectively. ATLAS, an accredited weathering farm/laboratory, forwarded field results to ORNL for review. ATLAS also forwarded documentation certifying both the age and measurements, and stated that the test specimens were under their control for the exposure time in question.

We used a portable solar spectrum reflectometer to measure the solar reflectance of the painted metal roof panels. The device uses a tungsten halogen lamp to diffusely illuminate a sample. Four detectors, each fitted with differently colored filters, measure the reflected light in different wavelength ranges. The four signals are weighted in appropriate proportions to yield the solar reflectance. The device is accurate to within ±0.003 units (Petrie et al. 2000) through validation against the ASTM E-903 method (ASTM 1996).

A portable emissometer was used to measure the total infrared emittance based on the procedures given in ASTM C-1371 (ASTM 1997). The device has a thermopile radiation detector, which is heated to 180ºF (82ºC). The detector has two high-ε and two low-ε elements and is designed to respond only to radiation heat transfer between itself and the sample. Because the device is comparative between the high- and the low-ε elements, it must be calibrated in situ using two standards, one having an emittance of 0.89, the other having an emittance of 0.06. Kollie, Weaver, and McElroy (1990) verified the instrument's precision as ±0.008 units and its accuracy as ±0.014 units in controlled laboratory conditions.

Emittance Field Data for 70% PVDF base paint metals

Emittance measurements taken over a ten year period from Akzo Nobel (Fig. 5) demonstrate a slight increase in emittance, resembling the emittance trends seen by ORNL (Fig. 3). The infrared emittance of the painted metal roofs tested at the different exposure sites by ORNL and by Akzo Nobel show that changes in emittance are very similar across the different climates. Therefore climate is not a major factor in the change in emittance, and the slight increase in emittance helps promote a "cooler" roof.

Reflectance Field Data for 70% PVDF base paint metals

Data from Akzo Nobel (Fig. 6) show a drop in solar reflectance of only about 5% over 10 years, particularly for the lighter colors. Atofina data for similar color metals are superimposed on the Akzo Nobel results to show similarity of results. The Atofina data reveal the PVDF base paint systems retain reflectance through 15 years of exposure testing.

BASF PVDF pastel colors and their darker colors(Fig. 7) show little loss of reflectance proving that they remain resistant to climatic exposure. Over a nine year period there was little, if any, decrease in the reflectance of BASF blue and green samples (Fig. 7), and there is no discernable decrease in reflectance of BASF brown and black samples over a six year period (Fig. 8).

Data from Atofina, Solvay Solexis, Akzo Nobel and BASF shown in figure 8 provide a review of sustained performance for almost 35 years. The Atofina PVDF white metal shows that the reflectance remains relatively constant even after 35 years of exposure. The additional data (Atofina white, tan, red and black, and Solvay Solexis white in figures 6, 7 and 8) show the uniformity of reflectance among measurements from various manufacturers and prove the sustained maintenance of reflectance.

Conclusions

The field data provided by the metal roofing industry for polyvinylidene fluoride base paint metals show that these types of painted metals maintain their resistance to soiling for at least thirty-five years. Both the ORNL study and the Coalition results show that the loss of reflectance is very similar, and climate does not appear to be a factor affecting the loss of solar reflectance.

The infrared emittance increases slightly as exposure time increases. The uniformity of emittance measures for exposure in different climates shows that the emittance of the painted metals is not affected by climate.

References

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Miller, W.A., Cheng, M-D., Pfiffner, S., and Byars, N. (2002). "The Field Performance of High-Reflectance Single-Ply Membranes Exposed to Three Years of Weathering in Various U.S. Climates," Final Report to SPRI, Inc., Aug., 2002.

Petrie, T. W., Desjarlais, A. O., Robertson, R. H., and Parker, D. S. 2000. Comparison of techniques for in-situ, non-damaging measurement of solar reflectance of low-slope roof membranes. Presented at the 14th Symposium on Thermophysical Properties and under review for publication in International Journal of Thermophysics, Boulder, CO: National Institute of Standards and Technology.

Figure 1. The Envelope Systems Research Apparatus used for testing painted and unpainted metal roofing.

Figure 2. Exposure racks used at Atlas and Q-Lab for exposing PVDF metal roof samples.

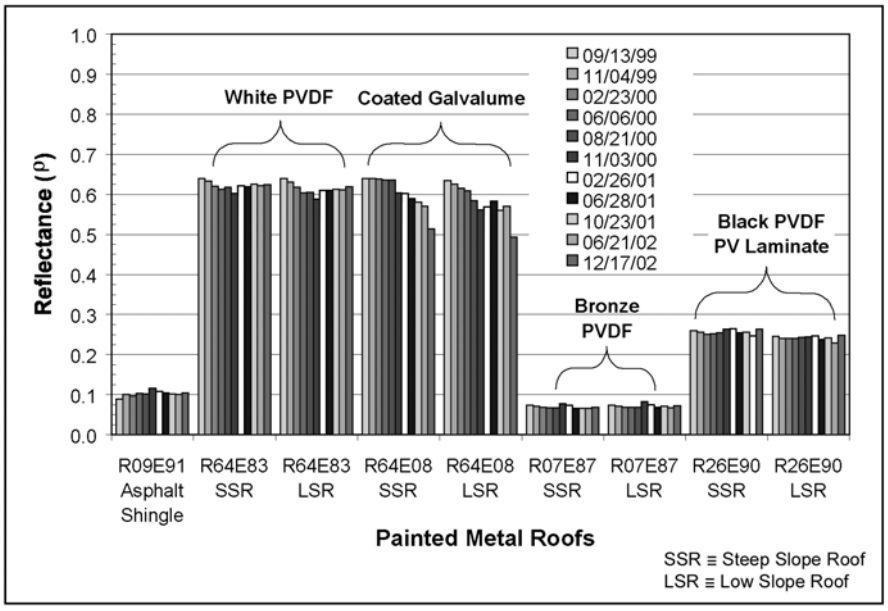

Figure 3. Solar reflectance of the painted metals exposed to east Tennessee's climate on the ESRA.

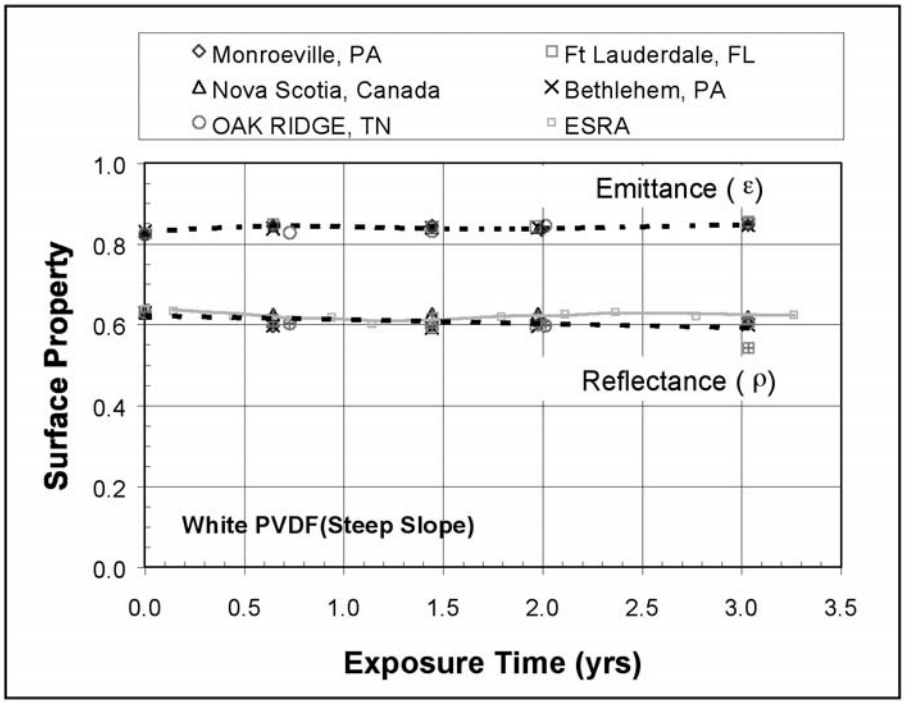

Figure 4. Solar reflectance and infrared emittance of white PVDF painted metal (R64E83) field tested at ORNL.

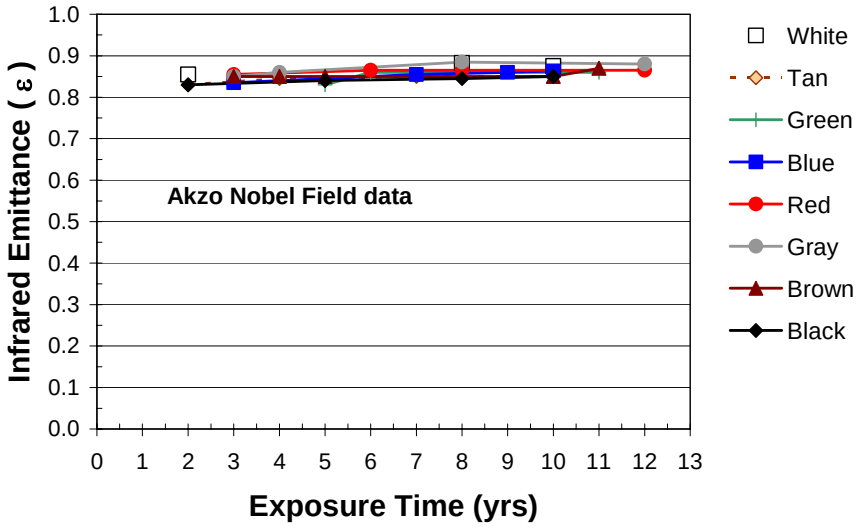

Figure 5. Emittance of Akzo Nobel PVDF base paint metals over time.

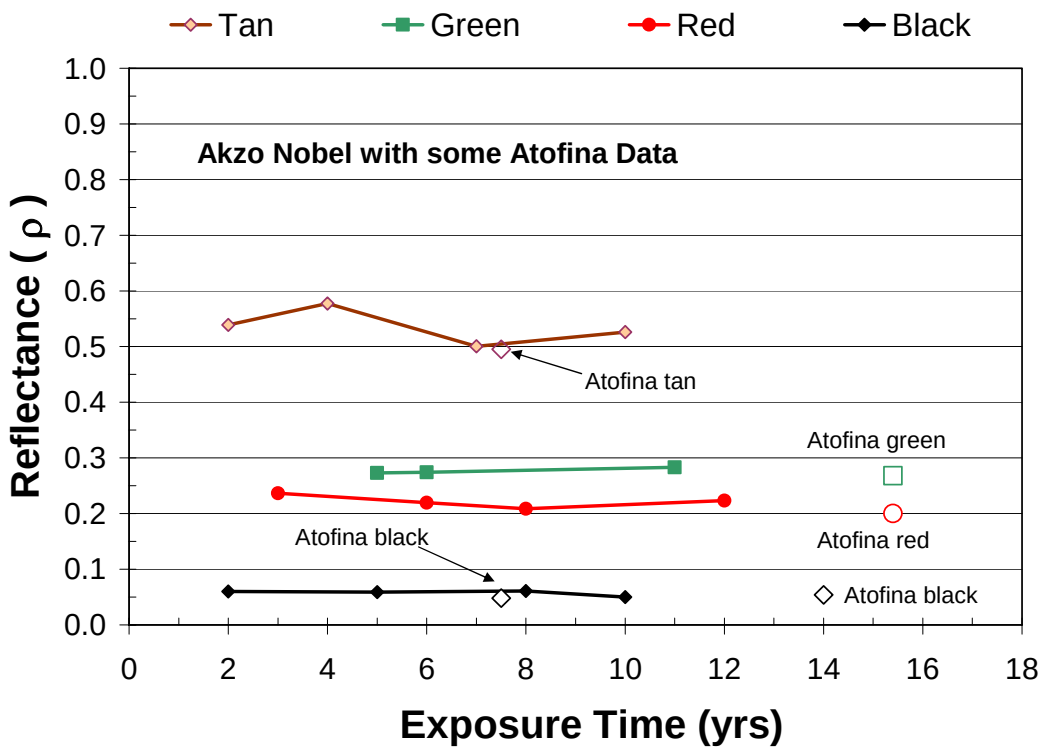

Figure 6. Solar reflectance of Akzo Nobel and Atofina PVDF base paint metal panels over time.

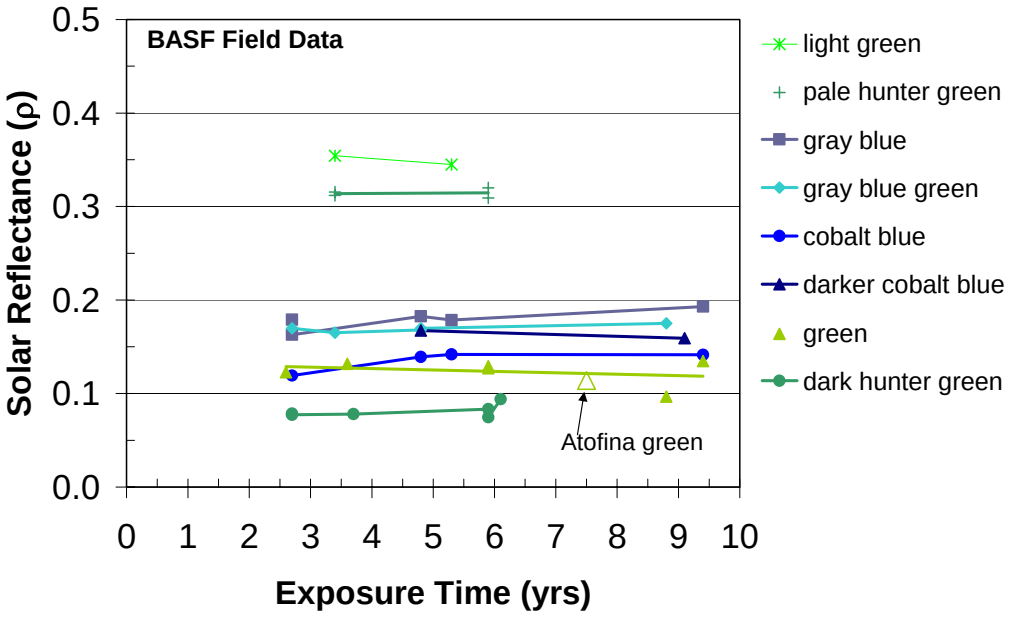

Figure 7. Solar reflectance of BASF PVDF base paint metal over time with Atofina data.

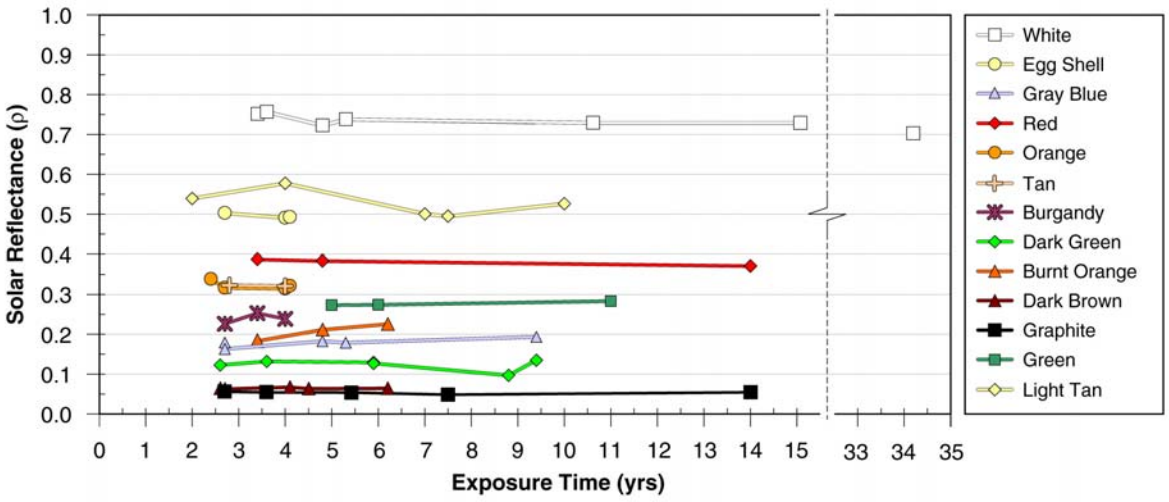

Figure 8. Solar reflectance of PVDF painted metals from BASF, Atofina, Akzo Nobel and Solvay Solexis.