Effectiveness of Cool Roof Coatings with Ceramic Particles

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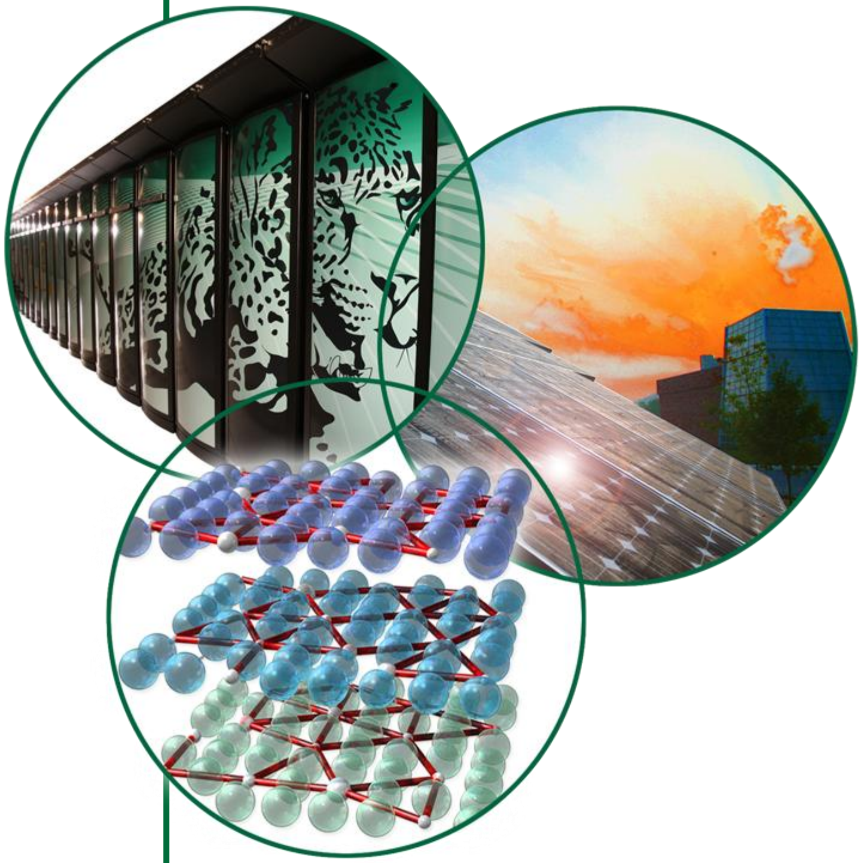

U.S. DEPARTMENT OF ENERGY

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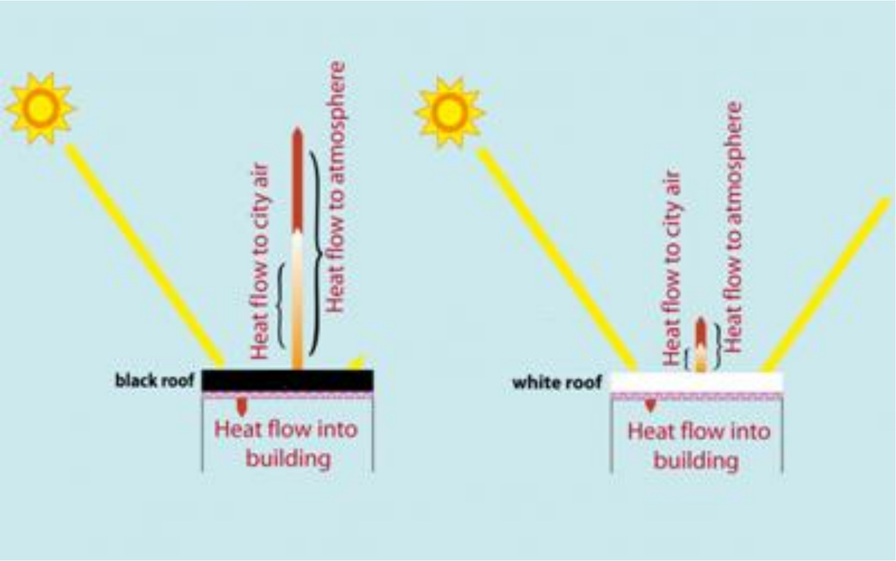
Outline

1. Introduction
2. Samples tested
3. Small scale tests – emittance, solar reflectance, thermal conductivity
4. Outdoor exposure in the RTRA – roof test facility
5. Conclusions

Introduction

- Cool roof systems have demonstrated reduced cooling loads, reduced peak loads, reduced heat island effect
- Cool roof systems are becoming part of codes and guidelines for energy efficient buildings
- Various ways to design roof to meet energy requirements: insulation, thermal mass, and radiation surface characteristics



Introduction

- Adding a solar high reflectance coating to a roof is a relatively convenient way to achieve cool roof performance.
- A variety of ‘cool roof’ products are available for various roof surfaces (Cool Roof Rating Council index of products).
- One of the variants among products is the incorporation of ceramic beads or particles in the coating mixture.
- The current study was conducted to assess the thermal performance of field applied coating products with ceramic particles.

Sample Preparation

- Roof coatings were applied as liquids and dried to form an elastomeric layer. Coatings were applied to EPDM.
- All coating materials tested appeared bright white.
- All but one of the coatings tested on the RTRA had ceramic particles added to the acrylic coating base.
- Two of the coatings were spray applied and the others were applied with a roller brush. Basecoats were used when directed by the manufacturer. Coating thickness was 9 mils to 23 mils.
- 12 by 12 inch samples prepared for small scale laboratory tests.
- 4 by 4 foot sections prepared for exposure tests on the RTRA.

Coatings Tested

All coatings appeared bright white. All products except C are commercially available and were tested as provided.

Sample A — acrylic coating with various sizes of ceramic particles

Sample B — latex/acrylic coating with ceramic particles

Sample C — acrylic coating (same as Sample E) with ceramic particles added (8% ceramic powder added by volume)

Sample D — highly reflective acrylic coating without ceramic particles

Sample E — acrylic coating without ceramic particles

Thermal Emittance

- Measured using the D&S emissometer according to ASTM C1371

Sample	Emittance from Oak Ridge National Laboratory	Emittance from Cool Roof Rating Council
A	0.86	0.91
B	0.83	0.88
C	0.88	N/A
D	0.86	0.87
E	0.89	0.88

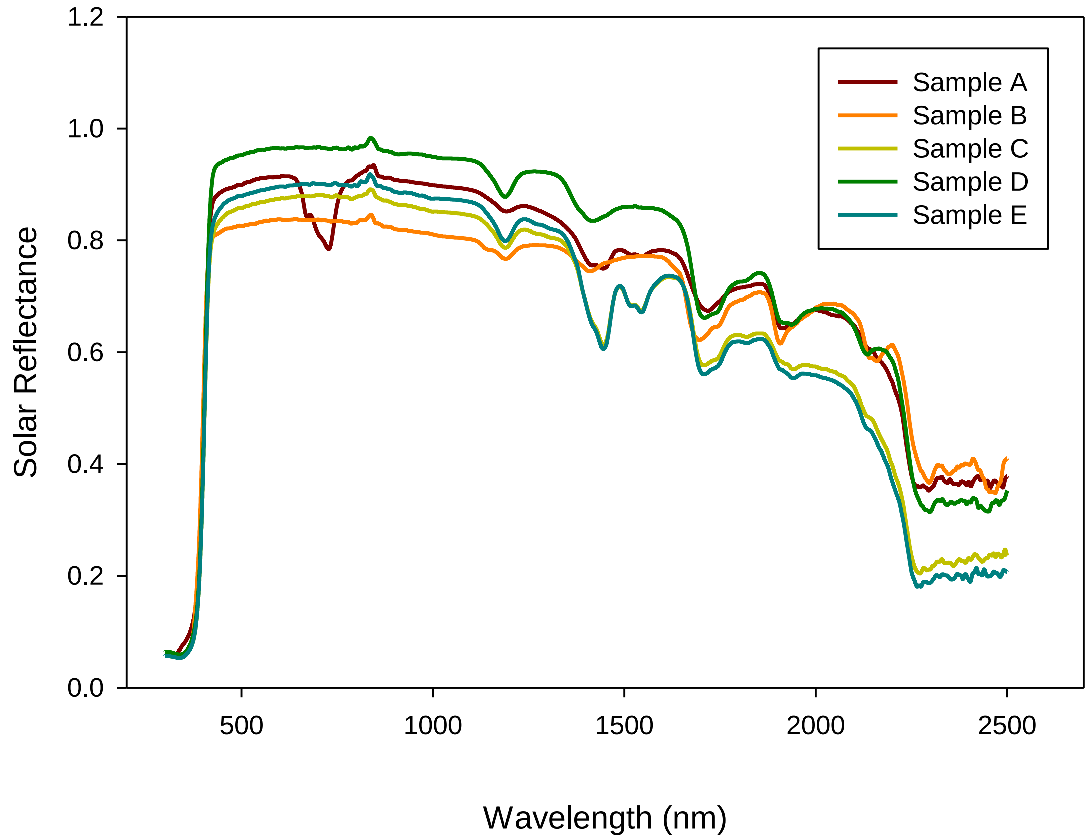
Solar Reflectance

- Solar reflectance measured using ASTM C1549
- ORNL reflectometer using selection b891 version 6 calibration

Sample	Initial Solar Reflectance from ORNL	Solar Reflectance from CRRC	Solar Reflectance from LBNL
A	0.810	0.83	0.83
B	0.776	0.83	0.77
C	0.786	N/A	0.79
D	0.876	0.92	0.88
E	0.814	0.83	0.81

Solar Reflectance

- Solar reflectance measured using ASTM E903
- Purpose to investigate if ceramic beads affect reflectance over specific wavelengths
- A, B, and C have ceramic beads and no beads in D and E
- All coatings exhibit similar behavior over all wavelengths



Thermal Conductivity

•Measured using a Fox 304 Heat Flow device according to ASTM C518.

•Thermal resistances for thin layers of paint are so small and at the limit of values the measurement device can measure.

•The small R-values make an insignificant contribution to the thermal resistance for a roof.

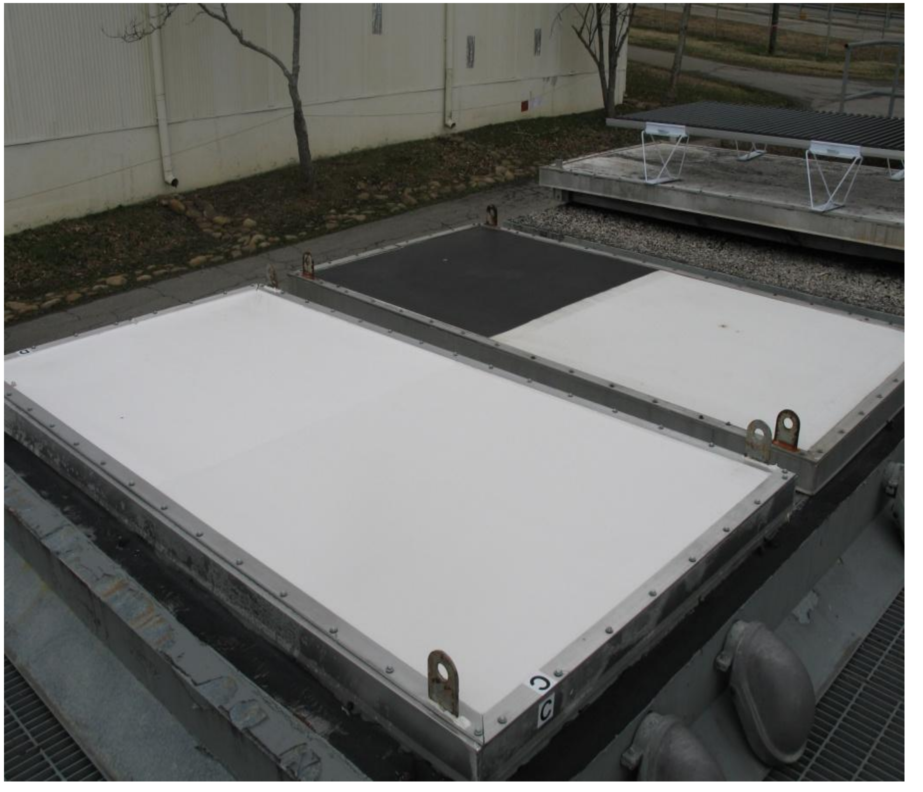
Sample	Thermal Conductivity (Btu in/hrft^2°F)	R-value as applied (ft^2°Fhr/Btu)	R-value if 20 mils applied (ft^2°Fhr/Btu)
A	6.74	0.002	0.003
B	0.88	0.024	0.023
C	2.11	0.012	0.010
D	3.35	0.006	0.006
E	5.28	0.004	0.004

Roof Tests

- 4- by 4- foot panels were tested on the RTRA (Roof Thermal Research Apparatus) in East TN

- RTRA is a small test building with:
  i) weather station
  ii) precisely maintained indoor temperature
  iii) instrumented roof
  iv) data acquisition system

- Tests started in March 2011 and data collected for 1 year.

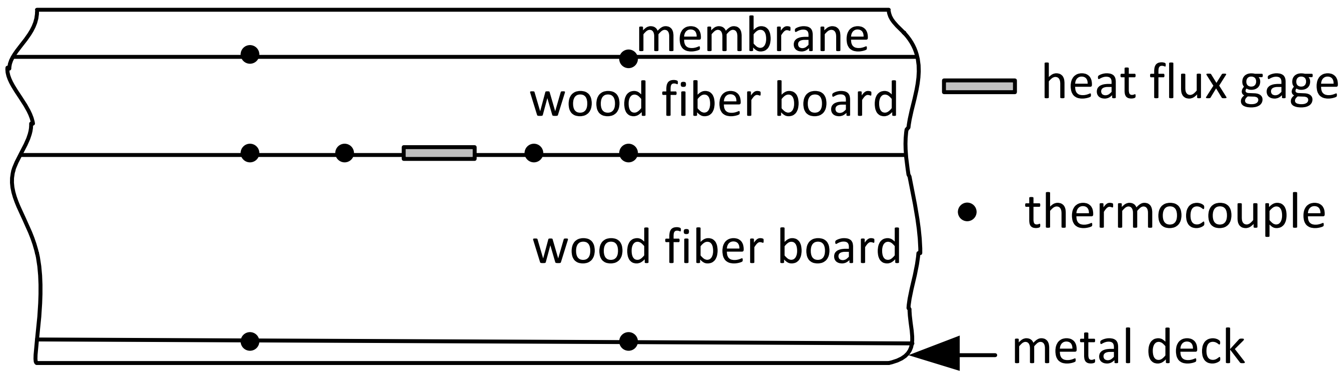


Instrumentation – Weather Station and Roof

Data is gathered every 15 minutes.

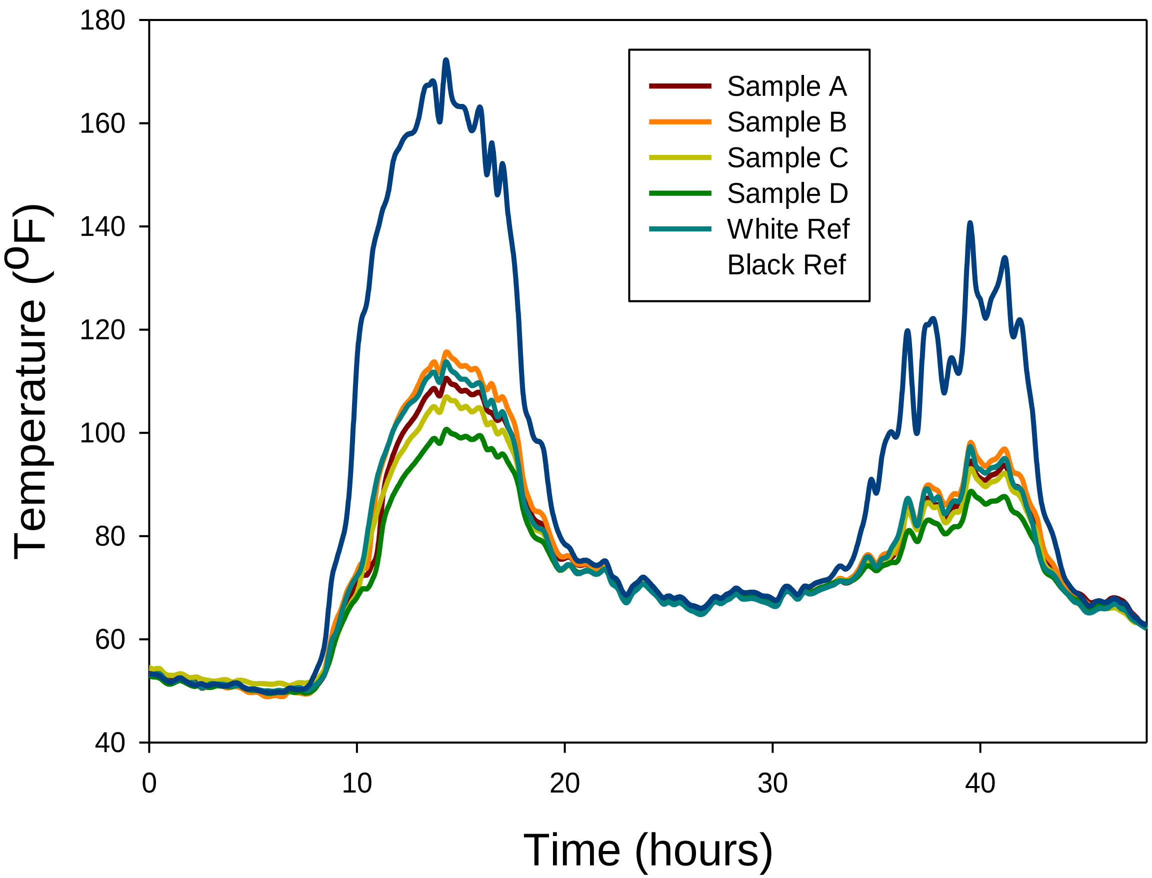
- Weather data (solar load, outside and inside air temperature, and wind)
- Temperature at multiple locations through the roof
- Heat flux measured at one location through roof

Roof construction has R-4 value, relatively low thermal resistance roof.



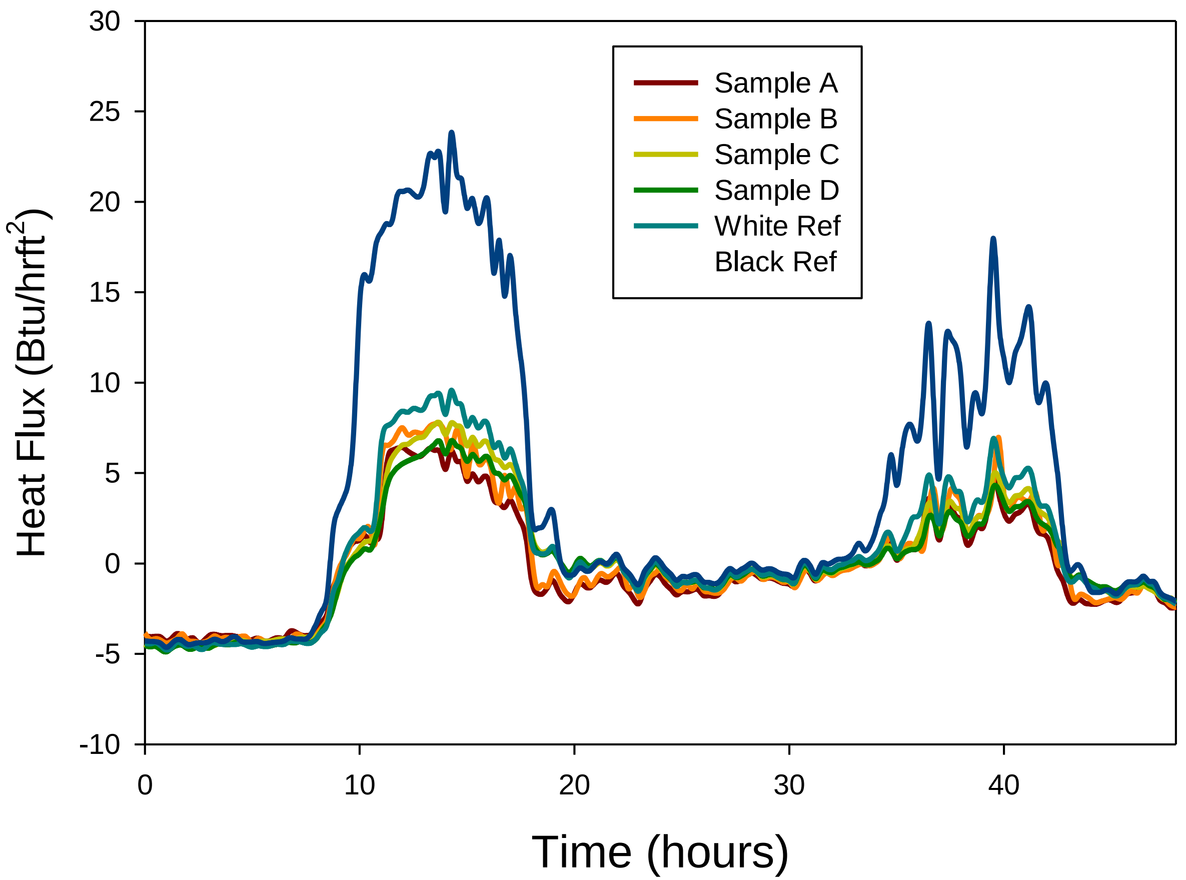
Example Temperature Data

•Temperature for two days in August, measured just below exposed membrane
•Black roof has highest temperature, high reflectivity paint the lowest



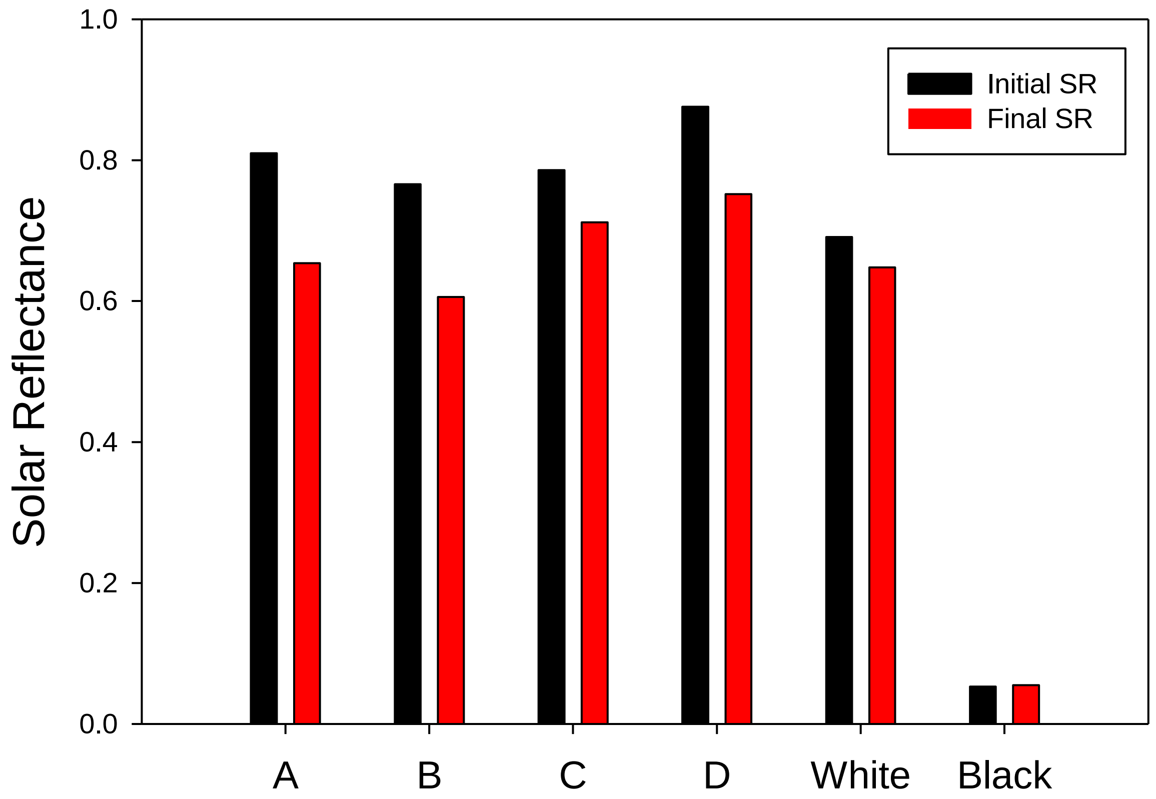
Example Heat Flux Data

- Heat flux is measured at the interface between the two layers of fiber board of the roof
- Heat flux for two days in Aug., first sunny and second with clouds



Solar Reflectance (SR) with Aging

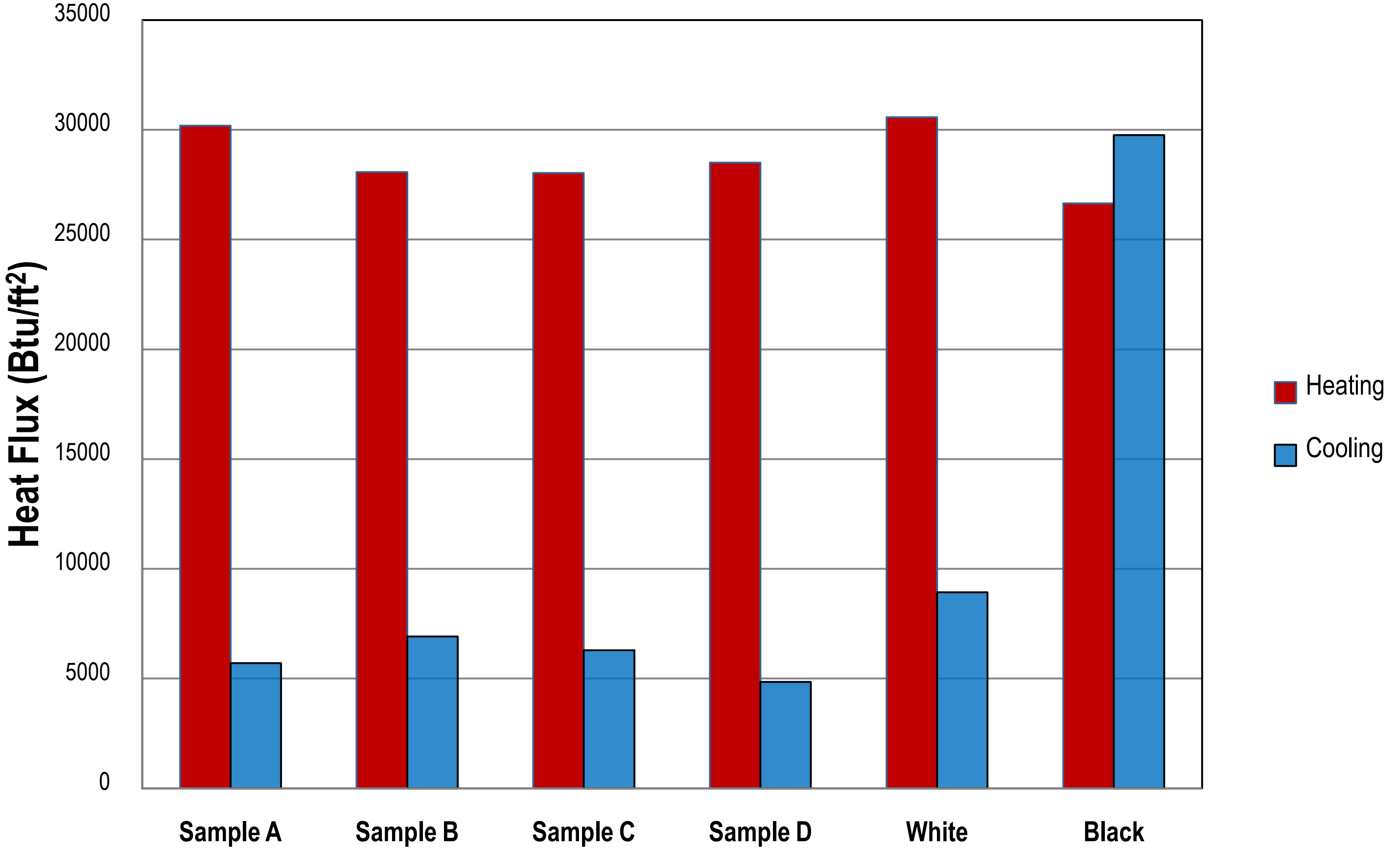
- SR measured at start of the test and after 15 months
- SR dropped by 10-20% for the coatings tested
- Coating with and without ceramic materials decreased in SR by similar levels



Heat Flux through Roof

•All coatings tested had lower cooling requirements than white reference roof

•Highest reflectance roof (no ceramics) had the lowest cooling requirement



Energy Cost Estimates

•Heat flux into the space must be removed through cooling by a 13 SEER air conditioner. A/C compressor uses electricity that costs $0.1168 kWhr.

•Heat flux out of the space must be supplied by a furnace that is 83% efficient and burns natural gas that costs $11.65/1000 ft^3.

•The value given in the table is US dollars required to heat/cool the space on a per square foot basis for one year for the roof tested.

	A	B	C	D	White	Black
energy cost in $/ft^2	0.463	0.445	0.438	0.432	0.467	0.630

Conclusions

- Thermal emittance and solar reflectance values were in reasonable agreement with measurements made by other groups and methods.
- Scans of solar reflectivity for coatings with ceramics over all wavelengths did not demonstrate signatures significantly different from acrylic coatings without ceramics.
- A high solar reflectance acrylic paint with no ceramic particles reduced the cooling load most significantly. Ceramic particles do not play a dominant role in solar reflectance.
- Ceramic particles did not significantly increase the thermal resistance of the roof based on the thin coating layers used (~20 mils).

- All coatings tested (with and without ceramics) significantly reduced the cooling requirements compared to the reference black surface.

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