Ceramic Coatings / Elastomeric Coatings

Ceramic Coatings Installed on Federal Buildings at Tyndall Air Force Base

Summary

Through the Federal Energy Management Program's New Technology Demonstration Program, the U.S. Department of Energy (DOE) provides technical and other support to Federal agency efforts directed at reducing energy consumption and costs in Federal buildings and facilities. One technology evaluated through a demonstration project is a reflective coating for rooftops. Partners in the demonstration project included Lockheed Martin Energy Research Corporation, the manager of the Oak Ridge National Laboratory (ORNL).

The demonstration was done at Tyndall Air Force Base (AFB) in Florida. Tyndall's Florida Panhandle locale is considered ideal for a demonstration of the effect of radiation control coatings on roofs because of the high cooling load of buildings in this area. ORNL's Buildings Technology Center staff gathered, analyzed, and reported on the data to describe the effect of the coatings. Detailed results are available in two volumes of an ORNL technical report, Radiation Control Coatings Installed on Federal Buildings at Tyndall Air Force Base (ORNL/CON-439/VI and ORNL/CON-439/V2). To locate the reports, which are on the DOE Information Bridge web site, key in "Tyndall Air Force Base" on the Easy Search page.

This article provides a summary of the monitoring design, its implementation, and the decommissioning of the monitoring equipment. It also summarizes data that compare fresh coatings with weathered coatings and generalizations from models calibrated to the monitored roofs and buildings at Tyndall AFB.

Technology Monitoring

The suitability of radiation control coatings for widespread use in the Federal sector depends on their ability to perform near their initial level of solar reflectance for long enough to justify the investment needed to install them. They are a passive technology so no operating expenses are involved. The period of performance of this demonstration was not long enough to see if the coatings extended the service life of the roofs, which is a benefit often claimed for these coatings. Savings in cooling costs are the benefit of coatings that this project sought to evaluate.

To evaluate the savings in cooling costs, monitoring is required to follow the thermal performance of the roofs and the energy required by the buildings. To measure the thermal performance, the heat flows through the roofs as a function of inside and outside conditions is sufficient. The primary characteristic of roof coatings affecting thermal performance is solar reflectance as a function of time. Another characteristic usually of interest for thermal performance is the infrared emittance, which determines the ability of the roof surface to emit radiation at long wavelengths to the sky. The infrared emittances of the white coatings used were about the same as those of the uncoated roofs.

The solar reflectances of the radiation control coatings decreased as the coatings weathered. Laboratory techniques were relied upon to measure the changing solar spectrum reflectances. Samples of roofs covered by weathered coatings were removed periodically from the roofs and brought to the laboratory. Extra pieces of roof membranes were coated along with the roofs at Tyndall AFB and placed on the roofs to provide these samples (see Figure 1)

Figure 1. Uncoated patch (upper right) and coated piece (upper left) for solar reflectance samples at Tyndall Air Force Base

The project objectives included evaluation of both types of white coatings: latex-based products with ceramic beads added and acrylic elastomeric products. Both had titanium dioxide added to increase solar reflectance. The ceramic beads are clear borosilicate microspheres which, when added to the latex base, decrease the density of the coating. The beads did not appear to affect solar reflectance one way or the other. They did make it difficult to brush coat small sections on the roof of a fast food restaurant at Tyndall AFB, selected for its smooth-surfaced, single-ply membrane roof. Applying the ceramic coating left brush marks. An acrylic elastomeric coating brushed on smoothly next to the ceramic for side-by-side comparison of performance. The ceramic-coated patches seemed to attract dirt more than the smoother acrylic. When the coatings were fresh, the two coatings had nearly equal solar reflectances and performed the same, but the ceramic performance deteriorated more quickly in this situation. At our outdoor roof test facilities in East Tennessee, in side-by-side tests of white coatings with and without ceramic beads, where the coatings were roller applied on smooth surfaces, we have not seen any significant differences in performance of the two types.

Two other buildings at Tyndall AFB, a veterinary clinic and a convenience store, were selected to have their entire roofs covered with the ceramic coating (see Figure 2). These buildings had built-up roofs with gravel imbedded in the bituminous topping. The coating was applied to the rough-surfaced roofs with an airless sprayer. To monitor the expected energy savings, pulse-initiating kilowatt-hour electrical meters were installed in both all-electric buildings. The veterinary clinic is a small building with a moderately well-insulated roof; it has a weekday-only operating schedule and little internal load. It is heated and cooled by an electric heat pump. The convenience store is a medium-sized building with a moderately well-insulated roof. Its load characteristics are a 7-day per week schedule and heavy internal load from refrigerators and freezers. The veterinary clinic and convenience store are similar in architecture; both have stucco-covered cement block walls and built-up low-slope roofs. Large trees shade the convenience store, and this shading proved to be a significant variable in the analysis of the coatings' performance.

Figure 2. Convenience store at Tyndall Air Force Base.

The whole-building pulse-initiating meters were put in place before the project start, with the cooperation of Gulf Power, the electrical utility serving Tyndall AFB. Thus, several months of data from the veterinary clinic and the convenience store were gathered before the coatings were actually applied in July 1996. Data collection was continuous, except for occasional interruptions, through October 1997. The interruptions were due to monitoring equipment and instrumentation malfunctions typical of remote data acquisition. The baseline performance without coatings, performance with fresh and weathered coatings, and detailed descriptions of the convenience store and the veterinary clinic were sufficient to calibrate models for the effect of the coatings on electricity use for cooling and total energy demand of the two buildings.

Initial plans were to monitor the veterinary clinic and convenience store for four summers. At the end of the two summers of monitoring supported by the New Technology Demonstration Program, the solar reflectances of the coated rough surfaces seemed to have achieved fully weathered values. We also learned that the convenience store was scheduled for extensive renovation within a year. The decision was made to end all monitoring, retrieve the data loggers, and cut off all instrumentation lead wires to the roofs. Instrumentation embedded in the roofs was left embedded.

Comparison of Fresh Coatings and Weathered Coatings

Measured solar reflectances for the ceramic coating as installed on the two rough-surfaced built-up roofs (BURs) were 0.52 and 0.54, respectively, or about 0.53. Relative to the 0.09 reflectance of the uncoated BUR, these reflectances produce a significant decrease in solar radiation absorbed, from 1-0.09 or 0.91 of the incoming solar radiation, to 1-0.53 or 0.47. The solar reflectance of 0.53 is at least 0.2 lower than we have observed for similar fresh white coatings on smooth, low-sloped surfaces. On the smooth-surfaced fast food restaurant roof at Tyndall AFB, the ceramic coating and an acrylic elastomeric had initial reflectances of 0.76 and 0.80, respectively. The same acrylic elastomeric and a different ceramic coating at our roof test facilities in East Tennessee showed initial reflectances of 0.81 and 0.85, respectively.

Over the course of the project, from July 1996 through October 1997, the reflectance for the shaded rough BUR on the convenience store decreased to 0.42 while the coated roof reflectance at the veterinary clinic decreased to 0.50. On smooth, low-slope surfaces after several years of weathering we have observed values as low as 0.50 to 0.55.

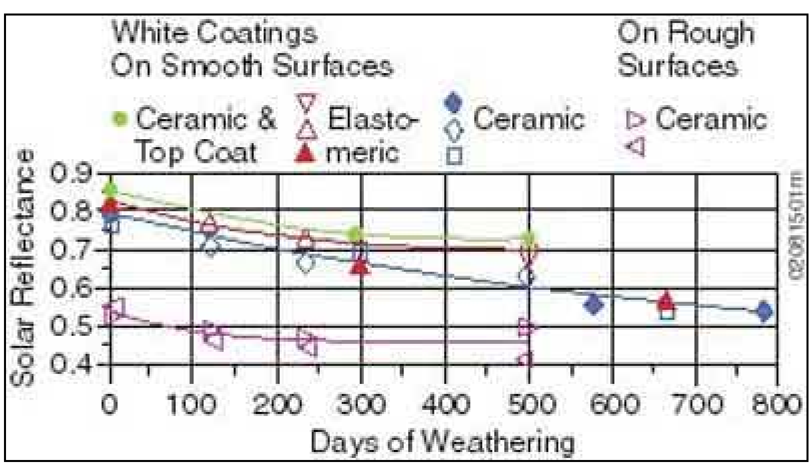

Figure 3. Behavior of the solar reflectance of various white coatings on smooth and rough surfaces as the coatings weather.

From the continuous records of roof surface temperatures from a coated area and an area left uncoated on both roofs, sunlit averages were generated to emphasize the effect of the coatings over time periods that would include variations in climatic conditions. Sunlit was defined as an hourly time period when the average coated surface temperature was at least 7.5°F (4.2°C) warmer than the corresponding average uncoated surface temperature.

For all sunlit periods in August, September and October of 1996, the coating on the shaded roof on the convenience store decreased its temperature an average of 12.9%. For the same time interval on the heavyweight concrete-decked roof on the veterinary clinic, the decrease was 12.3%. For the sunlit periods in August, September and October of 1997, the weathering decreased the average temperature reduction by the coatings to 11.9% and 10.7%, respectively.

Models for the thermal performance of the roofs, using measured inside and outside surface temperatures, predicted the deck heat fluxes for both roofs. They were calibrated to the measured heat fluxes through the 2 in. (5.1 cm) of polyisocyanurate foam insulation under each BUR. The August through October 1996 decreases due to the coating were 58% for the convenience store and 55% for the veterinary clinic. Both locations showed 48% decreases for August through October 1997. Percentage decreases for heat fluxes are larger than for outside surface temperatures because heat fluxes are the result of temperature differences. Using degrees Fahrenheit or Celsius, there are relatively larger percentage changes in the differences between the coated vs. uncoated outside temperatures and the almost constant inside temperatures in the roofs than in the coated vs. uncoated outside temperatures.

Unconditioned plenums under much of the roofs, with insulated ducts for distribution of conditioned air to the spaces under the plenums, complicated the relation between decreases in deck heat fluxes and decreases in building cooling load. We failed to observe significant decreases in total power demand after the roofs were coated. This suggests that the deck heat flux decreases were much larger than cooling load decreases for these buildings.

For more insight into the effect of the coatings on building energy use, whole building models for the public domain program DOE-2.1E were constructed with the architectural details and operational features of each building. They were subjected to Typical Meterological Year (TMY) climatic data for Apalachicola, Florida, near Tyndall AFB. Verification of model accuracy was achieved by comparing measured and predicted building power for 8 weeks throughout the project when air temperatures measured above the roofs approximately matched the TMY dry bulb temperatures. The shading for the convenience store roof, and to a lesser extent for the veterinary clinic roof, was provided in DOE-2.1E with vertical 50% transparent rectangles south of the building. The rectangles were sized to produce the roof shading observed in mid-August.

The effect of shading and the coating on annual energy use for the convenience store showed that the shading and the coating were equally effective in decreasing cooling energy use. Neither did much because of the heavy internal loads for the convenience store. For shading the effect was a 0.9% decrease in predicted annual cooling energy use; for the coating the effect was a 0.8% decrease. The coating was more effective for the veterinary clinic, despite its heavyweight roof and the plenum under all its roof. DOE-2.1E predicted a 7.4% decrease in annual energy use for cooling with a fresh coating compared to no coating.

Unconditioned plenums under roofs is a common feature in commercial buildings. The roofs at Tyndall AFB were moderately well-insulated, with 2 in. (5.1 cm) of foam insulation. Within the limits of DOE 2.1E for handling thermally massive components and plenums, additional modeling was done for the veterinary clinic to study the effects of the roof surface, the insulation level, and the plenum, holding all other features in the model constant. In the additional modeling, first the thermally massive concrete deck was replaced by a lightweight metal deck. Then the plenum was removed. Without a plenum, a smooth-surfaced metal roof was postulated, and its insulation was decreased from 2 in. (5.1 cm) to none.

The fresh coating on the veterinary clinic without modifications saved 7.4% of the annual cooling energy. The modifications showed progressively more and more annual cooling energy use as the amount of insulation in the uncoated roof decreased. They also showed more and more savings with the coating. In the case with the uninsulated metal roof and no plenum, annual cooling energy savings with the fresh coating increased to 43%. This case also showed that estimates of energy savings over the lifetime of a coating should be done with solar reflectances for the weathered coating; otherwise, the estimates are too optimistic. For this case, savings estimates with fresh coating solar reflectances were about 50% larger.

DOE-2.1E also yielded estimates of net annual energy savings due to the coatings, which accounted for the relatively small increase in heating costs because the coatings kept the roofs cooler in winter, too. The annual energy savings were combined with data for installing the coatings to yield annual savings in energy costs, initial installation costs, and simple payback times for conditions at Tyndall AFB. Using weathered coating solar reflectances for the veterinary clinic as built, simple payback time was over 70 years. The simple payback times decreased as savings increased but exceeded the projected coating life of 10 to 15 years except on the uninsulated metal roof. For it, with weathered reflectances, the simple payback time was 5 years (see Figure 4). These simple payback times did not address other possible benefits of coatings, such as extending the life of the roof membranes they cover.

Conclusions

The mission of the Federal Energy Management Program, which sponsored this project, is to reduce energy use and associated expenses in the Federal sector. Federal buildings are located in various climates and are constructed and operated in many ways. The roofs of many of these buildings in cooling-dominated climates are potential candidates for application of radiation control coatings. This project yielded detailed data on the thermal performance of radiation control coatings in less than ideal circumstances for maximizing the energy savings from the coatings: rough-surfaced roofs with moderate levels of insulation. It has also provided evidence on the performance of the coatings over time sufficient for their solar reflectances to decrease due to weathering effects. The models of the buildings whose roofs were coated under the conditions at Tyndall AFB reflect the effects of these specific conditions on energy savings. Generalizations of the models to buildings with different roof surfaces and various levels of roof insulation show the range of economic benefits from energy savings in Tyndall AFB's climate.

Radiation control coatings are not for every roof. This project provided data and procedures to help federal building managers decide if possible energy savings make their roof a viable candidate for a coating. The technology demonstrated in this project is commercially available and can be applied to most roof surfaces. Whether or not it should be applied to a particular roof is a decision best made on a case-by-case basis.

Energy Seal Coatings

It has been determined that a ceramic modified roof coating does not significantly increase the roof coatings ability to reduce heat loads on a roof, over a non-ceramic roof coating. However, it was observed that the ceramic modified roof coating was more abrasion resistant than the non-ceramic roof coating.

Save Money !

Reflect and Protect

with…

Energy Seal Coatings