Roof Coatings for Reducing Warehouse Condensation Potential[1]

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ABSTRACT

White ceramic roof coatings were found to be significantly better than galvanized sheet metal in reducing the solar heat gain on roof panels like those used for the roof of a farmers stock peanut warehouse. However, the ceramic coatings were not better than a white acrylic latex paint in reducing solar heat gain. After four years of testing, there was no apparent difference in the durability of the ceramic coatings or paint. The ceramic coatings were reputed to have good thermal insulating properties, but these were not apparent in the study. The maximum mean two-hour temperature during the study occurred on September 14, 1991 with the galvanized control panel reaching a high of 69.3 C. The ceramic coated and painted panels due to their solar radiation reflective properties were approximately 19 C cooler than the galvanized control and approximately 14 C warmer than ambient temperature.

Key Words: Reflectance, roof coatings, solar radiation, insulation, painted surface, peanut warehouse, storage.

The potential for condensation to occur in farmers stock peanut warehouses increases for each degree increase of overspace temperature above ambient. Peanuts often enter storage at a temperature above 20 C and at greater than 9% moisture content. During normal storage in the Southeast, these peanuts will equilibrate at about 7% moisture content at 10 C and 60% relative humidity (6). The excess heat and moisture are released to the overspace air in reaching this condition. Since most peanuts are stored in uninsulated metal warehouses, condensation occurs when the metal surface temperature drops below the dew point of the overspace air. Condensation often occurs in quantities sufficient to run on the underneath side of the roof until it reaches a purlin where it drips off, forming drip lines across the peanut mass. Drip-line peanuts often contain high levels of aflatoxin (5). Preventing heat buildup in the warehouse during the day and reducing the temperature difference between the roof and overspace air at night would reduce the condensation potential.

Space age technology has resulted in a number of new products being brought to market. Among these have been roof coatings reported to provide good insulating properties against heat transfer in addition to being good solar radiation reflectors (3,4). Anderson (1) states that the application of radiation control coatings to exterior roof and wall surfaces can effectively block solar heat gains through these surfaces. Blocking the solar heat gain through the roof reduces the heat gain in the overspace, especially if the overspace is poorly ventilated or not ventilated. Bucklin *et al.* (2) reported results from several studies on the effectiveness of reflective roof coatings for reduction of solar heat gain in livestock and poultry housing.

[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be available.

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Coatings were found to be effective in reducing the inside temperature 2 to 3 C in totally enclosed poultry housing with no designed ventilation. Little temperature reduction was measured in well ventilated livestock and poultry housing.

Surface temperature of galvanized sheet metal panels having three different coatings, two ceramic coatings and an acrylic latex paint, were measured. The objective was to determine surface temperature difference between these panels and the plain galvanized panel typically used on a peanut warehouse.

Materials and Methods

Four, 61-cm^2 galvanized sheet metal panels, 0.45 mm (26 gauge) thick were randomly located on a frame with six other panels, two rows of five panels per row. The frame holding the panels was constructed from 3.8 cm by 8.9 cm lumber and the panels were secured with small sheet metal screws, one in each corner of each panel. This frame, serving as a roof, was mounted at a 45° angle on a steel frame covered with 26 gauge sheet metal that had a baked-on white paint finish. The sheet metal frame represented a portion of a naturally ventilated warehouse and was secured to a concrete pad with the roof facing due South (Fig. 1). A 2.5-cm slot was cut just below the roof in front and back so that air could flow under the roof to represent a naturally ventilated warehouse. A door on one end of the structure provided access to attach thermocouples for temperature monitoring. When the panels were in place on the wooden frame, the exposed surface under each panel was a 52-cm^2 area.

The ceramic coatings used were "Astec 100" manufactured by ICC Corporation, Inverness, Florida (Treatment "A") and "Thermo-Shield" manufactured by Great Lakes Protective Coatings, Elk Grove Village, Illinois (Treatment "B"). The white paint used was "Wonder-Shield" 1801-01 exterior acrylic latex gloss manufactured by Devoe and Raynolds Company, Louisville, Kentucky (Treatment "C"). All of the materials were applied by brush. Multiple coats were applied perpendicular to the previous coat to obtain a total thickness of 27 mil.

Three type-T thermocouples were attached to the underside of each panel. These thermocouples were placed 22-cm apart on a diagonal line running from southwest to northeast. The second thermocouple was centered in the panel. Bare thermocouples were secured to the panels with a small amount of thermal epoxy adhesive. Thermocouples were scanned once a minute and an average recorded at two-hour intervals with a CR-7 Campbell Scientific data logger and a cassette recorder. Data were collected during four years as follows: March 13-August 3, 1989; May 4-October 2, 1990; March 13-December 31, 1991; and January 1-October 19, 1992. Data were analyzed statistically using analysis of variance procedures and Duncan's multiple range test for determining if significant differences in temperature existed for panel treatments. Analyses included comparisons of the daily 2-hour maximum or minimum temperatures of the unpainted panel with the maximum or minimum temperatures of the other coated panels for the corresponding 2-hour period.

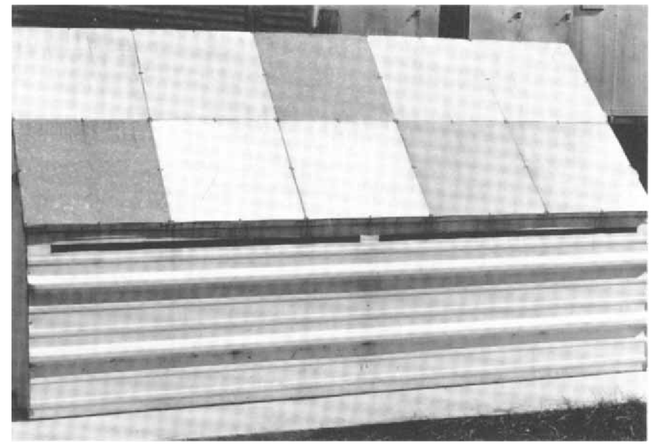

Fig. 1. Frame to simulate a farmers stock peanut warehouse with 45° roof slope facing due South for temperature measurement of panels with various coatings (finishes).

Results and Discussion

Results of data analyses to determine if significant differences existed in panel temperatures for the various treatments are summarized in Table 1.

The maximum (2-hour) temperatures for the unpainted panel (control) and painted panels for the same two-hour period are shown graphically in Fig. 2. For the 12:00 noon to 2:00 p.m. mean temperature scan on September 14, 1991, the control maximum temperature was 69.3 C. This maximum was reached when ambient temperature was 35.9 C. For the same time period, maximum temperatures for panels A, B, and C were 50.6, 52.6, and 49.8 C, respectively. Treatment B was higher than Treatment C in all four years and slightly higher than Treatment A in all years except 1990. Minimum panel temperatures during the test periods are shown in Fig. 3 with all panel treatment temperatures being less than the control panel, except in 1991 and 1992, when the temperature difference was small. The minimum control panel temperature during the test, -7.8 C, was reached on January 17, 1992 for the 6:00 to 8:00 a.m. mean temperature scan. The corresponding ambient temperature was -5.6 C and treatment panel temperatures

Table 1. Mean maximum and minimum temperatures, C, for panels with various coatings.

	1989 (C)			1990 (C)			1991 (C)			1992 (C)		
Panel (Treatment[1])	Total Days	Mean Max[2]	Mean Min[2]	Total Days	Mean Max[2]	Mean Min[2]	Total Days	Mean Max[2]	Mean Min[2]	Total Days	Mean Max[2]	Mean Min[2]
Control	134	40.7a	17.2a	151	52.2a	19.9a,b	282	46.1a	15.0a	292	44.2a	13.3a
A	134	32.1b	15.9a	151	40.4b	18.8b	282	34.4b	14.3a	292	32.0b	12.8a
B	134	32.3b	15.9a	151	39.8b	18.8b	282	35.4b	14.2a	292	33.9b	12.6a
C	134	32.2b	16.0a	151	40.4b	18.8b	282	34.8b	14.3a	292	32.0b	12.7a
Ambient	134	26.3c	17.2a	151	31.8c	20.2a	282	25.4c	15.9a	292	23.7c	14.4a

[1]Treatment: Control = uncoated galvanized panel - new 1989; A = Astec 100 ceramic coated panel; B = Thermo-Shield ceramic coated panel; C = Wonder-Shield latex painted panel; ambient = outside air.

[2]Treatment means within a column, followed by a common letter are not significantly different at the P = 0.01 level as determined by Duncan's Multiple Range Test.

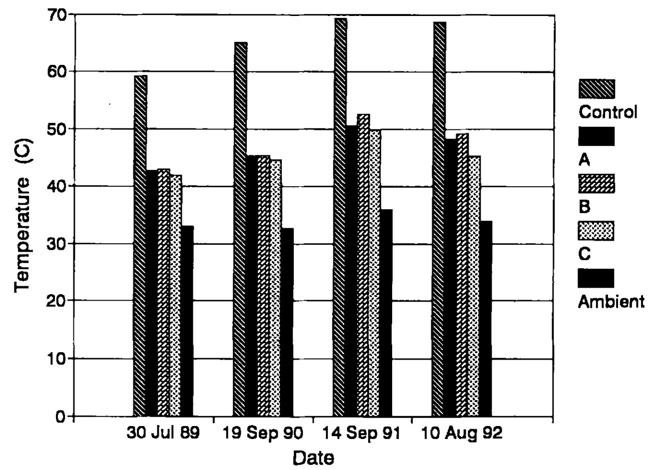

Fig. 2. Maximum two-hour mean temperature for the galvanized control panel with corresponding ambient and coated panel temperatures.

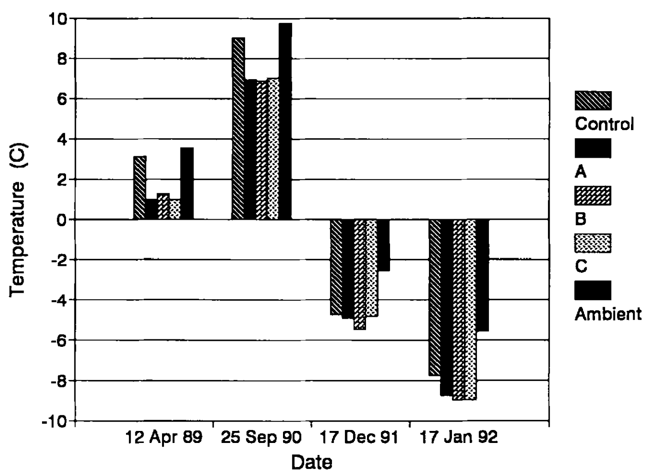

Fig. 3. Minimum two-hour mean temperature for the galvanized control panel with corresponding ambient and coated panel temperatures.

for treatments A, B, and C were -8.7, -9.0, and -9.0 C, respectively. The maximum and minimum panel temperatures do not necessarily coincide with the maximum or minimum ambient temperature. Maximum solar radiation during the day and sky radiation at night are influenced more by cloud cover than by ambient temperature. Therefore, the maximum and minimum ambient temperature can differ considerably from the time period for maximum and minimum panel temperature.

Table 1 lists the mean maximum and minimum temperatures for each year of the study. These means were calculated using the daily maximums and minimums. There were no significant differences among the maximum means for any of the coatings, but there was a difference between the control and the treatments (95% confidence level). There was no significant difference between the mean minimum temperatures for the control and treatments; however, the control had a slightly higher minimum temperature than the treatments. In calculating the mean maximums and minimums, haziness or cloud cover were not considered. The coated panels and control maximum temperatures were higher than the ambient temperature because of the absorption of solar radiation. Heat absorption by the control was approximately twice as great as the treatments. As expected, the minimum temperatures for the control and treatments were less than the ambient temperature. Sky radiation is the main reason for the lowering of the control and treatment panel temperatures. The claimed thermal insulating effect of the ceramic coatings was not apparent in these tests.

Conclusions

Both white ceramic roof coatings and white paint greatly reduce the solar heat load on metal roofs as compared to unpainted galvanized metal. By reflecting much of the incident solar radiation, less heat was absorbed and radiated to the stored peanuts. A good ventilation system will remove this additional heat, but a cost is incurred for fan operation, and there is additional peanut weight loss.

Statistical analyses of data and visual observations indicated that the white ceramic coatings were not superior to a good white latex paint in reducing the temperature of galvanized roofs. Both ceramic coatings and the latex paint were equally effective in reflecting the incident solar energy. None of the treatments provided any thermal insulating value as indicated by a roof surface temperature above ambient temperature at night. The bare galvanized roof maintained a slightly higher temperature at night than any of the treatments, but not enough to be significant. After four years of weathering, there was no visual evidence in breakdown, either of the ceramic coatings, latex paint, or galvanized surfaces.

Based on these test results, a white ceramic coating or paint for reflecting solar radiation from a peanut warehouse is preferred to bare galvanized sheet metal. Material and application costs would dictate the material to be used since both ceramic coatings and the paint appear equal in durability after four years of exposure to prevailing weather conditions.

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