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ALUMINIUM PAINT: An Effective Radiant Barrier For Low-Income Tropical Roofing

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ABSTRACT

In the context of research, seeking economical means of reducing downward heat transfer into typical residential houses in the English-speaking Caribbean (in which the predominantly used roof cladding is corrugated galvanised sheet steel), the authors found that long-established, internationally-accepted thermal property values were not necessarily applicable to the materials currently in local use. In particular, discrepancies were identified between the published and the measured thermal emissivity values for aluminium paint and oxidised galvanised steel, and the research investigation clearly identified lower-than-previously-accepted values for the emissivity of locally produced aluminium paint. This lower emissivity indicates potential for the use of such paint as a bonded-on radiation barrier (RB) to reduce the heat radiated downward from the underside of such cladding. Published values [1,2,5] *give the longwave emissivity of oxidised galvanised steels as being less than 0.30, while that of aluminium paints is given as between 0.27 to 0.67.*

This paper presents the methodology and results of steady-state, longwave emissivity testing of (a) aluminium paint and (b) oxidised galvanised steel, which were respectively measured at (a) 0.22 to 0.24, and (b) 0.40 to 45.

1.0 INTRODUCTION

Radiant barriers in the form of aluminium foil surfaces have for some time been the focus of international research [3,4,6,8,11] aimed at reducing downward heat intrusion through the roofs of buildings. The longwave emissivity testing reported below is a follow-up to the study [7,9,10] which demonstrated the potential of aluminium paint for reducing the heat radiated from the underside of aged galvanised steel cladding. The research is significant for the following reasons:

(i) The general unavailability of foil-based products in the Caribbean for use in buildings applications,

(ii) the relatively low cost and ease of application of this paint-based surface treatment, and

(iii) the prevailing use of corrugated galvanised (zinc-coated) steel sheeting as roof cladding in the Caribbean.

Subjective observation in the field indicated that a typically clad unceilinged house with a cladding undercoat of aluminium paint is significantly cooler than a house clad with galvanised steel left untreated. This led to the examination of aluminium paint as a potential radiant barrier. Previous research [7,9,10] has also demonstrated reduction in transmitted thermal energy as a result of applying aluminium paint onto the underside of oxidised galvanised steel cladding.

A radiant barrier consists of a surface of low emissivity (0.05 - 0.15[12]) or high reflectivity relative to longwave radiation, and in practice is usually a polished aluminium foil surface facing an air space. Published values give the longwave emissivity of oxidised galvanised steel as 0.25[1] to 0.28[2,5]; for aluminium paint, the published values range from 0.4 to 0.6[1,5] and 0.27 to 0.67[2]. The published values therefore suggest that, at best, the radiant-barrier performance of aluminium paint would be worse than

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experience (as indicated by sensory comparisons between painted and unpainted cladding undersides under hot conditions) suggests that aluminium paint has significantly lower emissivity than aged galvanised steel. To verify experience from the field, and to lay the foundation for further research, longwave emissivity testing was performed on aged galvanised steel (a) untreated and (b) treated with two coats of brush-applied aluminium paint. The paper presents the methodology and results of this investigation.

2.0 EXPERIMENTAL METHOD

2.1 Apparatus

A 60cm x 60cm copper plate, 6mm thick, supported on a wooden frame was used to provide a constant temperature surface (**Figure 1**). The plate was heated with a commercially available heating tape secured to its upper surface as shown in **Figure 2**. A variable transformer was used to control the voltage across the heating tape, and consequently the heating current

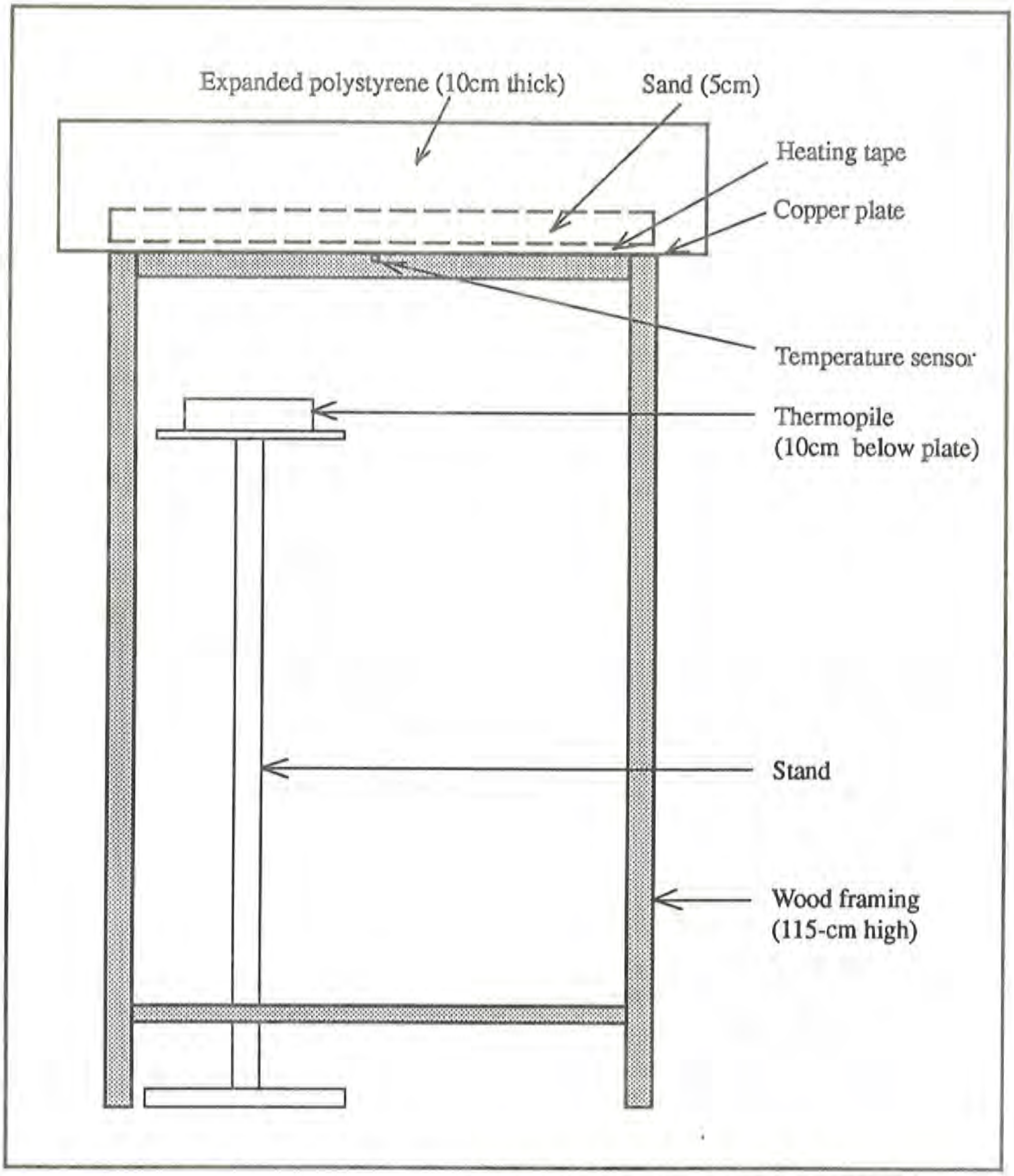

Figure 1: **Schematic of Longwave Emissivity Measurement Set-up (N.T.S.)**

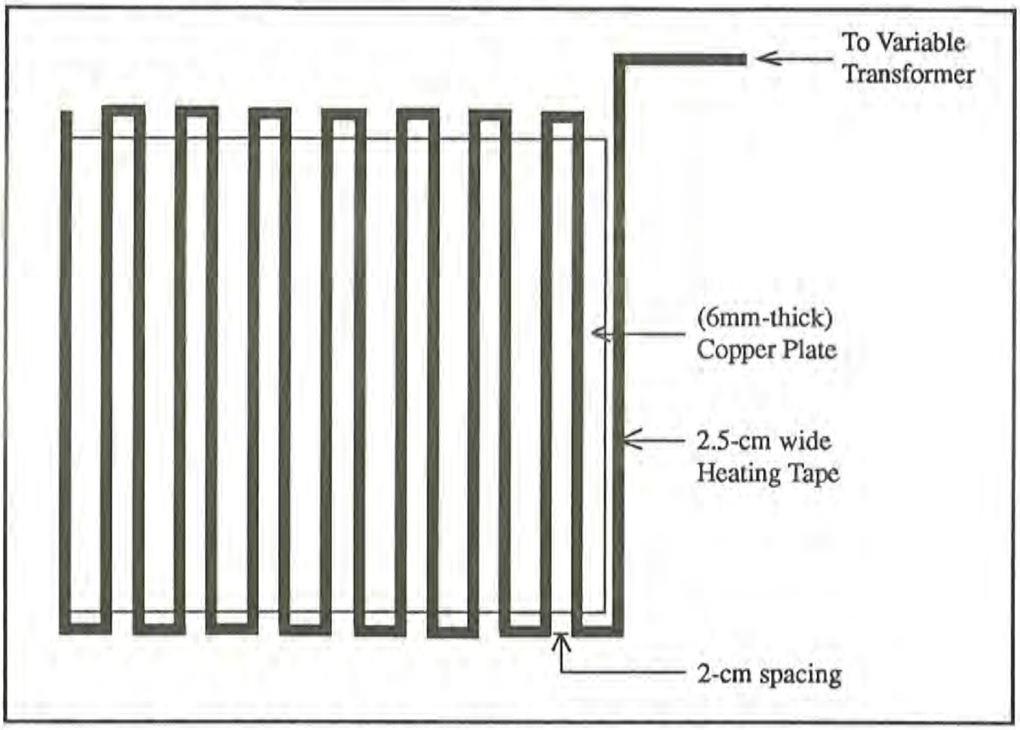

Figure 2: **Schematic of the Layout of the Heating Tape on the Copper Plate**

through. By this method, the output of the heating tape was controlled to maintain the desired test temperature for each test surface. Dry sand to a depth of 5cm was placed over the heating tape to improve thermal contact between the tape and plate and also to provide a stabilising heat capacitance. The top and sides of the copper plate/sand were insulated with 10cm thick expanded polystyrene as shown in **Figure 1**.

The radiant energy emitted by the surfaces under test was detected with a thermopile (**Figure 3**) with sensitivity 7×10^{-7}V per °C of effective radiation temperature difference at 20°C. The thermopile output was measured with a galvanometer (sensitivity $2\,\mu$V per cm scale deflection, precision ± 3%). The thermopile was supported 10cm below the radiating surface under test.

2.2 Procedure

With typical cladding temperatures in the field varying between 30°C and 65°C, a mean value of 47.5°C was chosen as the steady-state temperature at which to measure the emissivity of the selected surfaces. It should be noted that within the (thermodynamically) small range of temperatures, variation of emissivity with temperature is not significant.

Preliminary tests on the exposed underside of the heated copper plate indicated that the temperature spread across its surface was within ±0.5°C at a plate temperature of 47.5°C. At a steady-state radiating temperature of 47.5 ± 0.5°C, voltage output from the thermopile was recorded for the following test specimens, made of flat galvanised steel sheet, 20cm x 20cm x 0.4mm thick, having their lower surfaces in the following conditions:

(i) oxidised, untreated, but not rusted;

(ii) having two coats of brush applied aluminium paint;

(iii) having two coats of brush applied matt black paint

Steady state was considered as having being achieved when four consecutive (hourly) temperature readings were found to converge within 47.5 ± 0.5°C .

The specimens were bonded to the copper plate to obtain a test radiating surface. Voltage readings were taken for ten random positions with the thermopile held at a fixed vertical spacing of 10cm below the test surface. The voltage readings from a given surface were divided by the average value obtained from the matt black surface to derive the normal longwave emissivity of the test surfaces.

3.0 RESULTS AND DISCUSSION

The measured longwave emissivity ranges are presented in **Table 1**. These results show the potential of a commercially available aluminium paint as a radiant barrier for roofs made of galvanised steel (cladding). Both fresh and aged aluminium paint surfaces showed a 30% to 45% reduction in heat emitting potential compared with aged galvanised steel. The values obtained suggest that the basis for the published emissivity values (previously cited) need to be more carefully examined. The large ranges of emissivity values typically quoted for aluminum paint are of little direct practical use, but suggest that

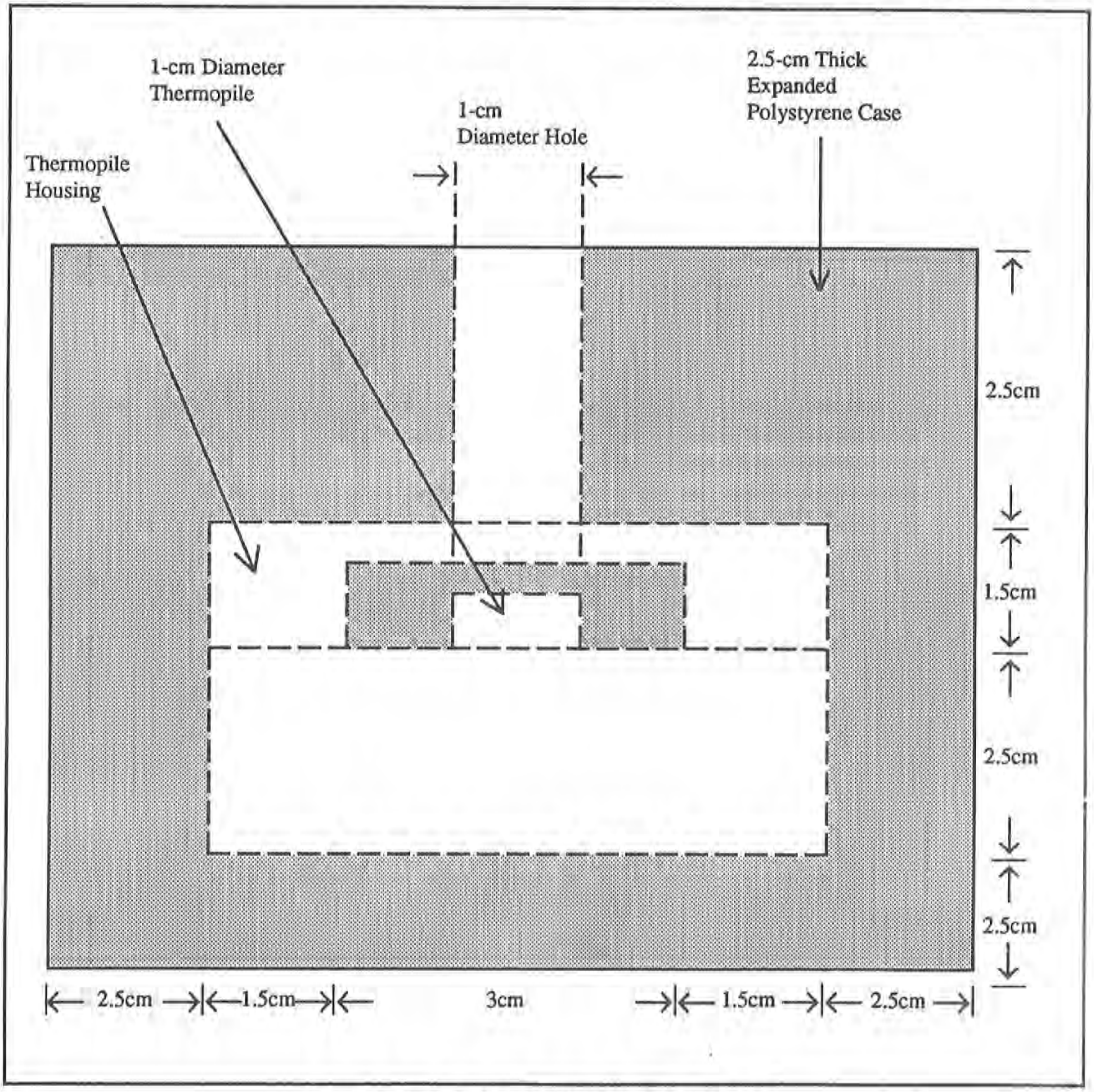

Figure 3: **Schematic Side View of Test Thermopile**

Type of Surface		Emissivity Range	Published Values
(i)	Aluminium paint (new surface)	0.22 - 0.24	0.27 - 0.67[2]
(ii)	Aluminium paint (1 year old surface)	0.27 - 0.29	
(iii)	Oxidised (aged) galvanised steel	0.40 - 0.45	0.25[1], 0.28[2,5]

Table 1: **Measured Longwave Emissivities on Galvanised Sheet Steel**

specifics of paint formulation, number of coats applied, texture of substrate, etc. may be of considerable influence. The published emissivity ranges for oxidised galvanised steel also appear open to question.

These results also highlight the risks attendant on the uncritical acceptance of internationally derived or published data. Instead, the researcher must be discerning, following through with all necessary localised in-house testing which may be necessary to define previously unexplored potential for perhaps innovative uses of materials. Nowhere is this need more critical than in the developing countries, with often scarce local resources, and traditional dependence on foreign technologies.

4.0 CONCLUSIONS

The results presented in this paper identify aluminium paint as a viable alternative to aluminium-foil-based radiant barriers for use in the Caribbean. The relatively low material cost (US\$0.80/m^2), the ease with which such a paint surface-treatment can be applied, combined with the no-maintenance advantage of negligible accumulation of emissivity-increasing dust on the underside of claddings, make undercoating with aluminium paint an attractive option. These results contain implications for low cost housing in particular, which can benefit from this innovative use of aluminium paint to significantly reduce daytime heat stress from solar heated galvanised steel cladding.

This work also demonstrates the risks involved in relying on published data acquired from materials and under conditions which are not necessarily applicable in local contexts. These concerns also relate to unmonitored developments which may have taken place in materials specifications since earlier tests were carried out. One of the primary objectives of the researcher should therefore be first-hand information derived from carefully-conducted experimentation.

The work did not measure the longwave emissivity of Aluzinc coated steel sheet, which has grown in use relative to galvanised sheet since the research was carried out. Sensory evaluations already carried out, together with an awareness of the composition of the coating alloy (55% Al, 45% Zn), both suggest a markedly lower emissivity compared to zinc-coated sheet. The enhanced corrosion resistance of Aluzinc, its growing use as a major roof-cladding material, and the implications of its surface emissivity for heat loads in tropical buildings together dictate the need for similar measurements to be also carried out on this newer material. However, there exists very large investments in both residential and industrial building stock in the Caribbean, roofed with corrugated galvanised steel sheet. There is considerable scope for the application of the aluminium paint treatment investigated above to buildings of these types.

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