A Review of Heat-reflective Paints

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ABSTRACT

In recent years, there have been a number of heat-reflective paints come on the Australian market. These provide the same visible colour range as standard products but perform quite differently in the infra-red region of the spectrum, reflecting more of the invisible part of the solar spectrum. Are they effective in meeting their advertised claims and if/when is there a benefit for their use? This paper reviews the advertising material and data to assess their value in a field where there is little sound scientific literature on some products and the technology of others is hidden for IP reasons.

Sunlight at ground-level incorporates incident radiation in the ultraviolet, visible and infra-red regions with wavelengths spanning 300 to 2500 nm. Any part of the solar spectrum where a surface absorbs incoming sunlight will cause an increase in surface temperature above ambient temperatures. If heat cannot be re-radiated to the sky, it will conduct through roof spaces towards the ceiling and radiate downwards through insulation batts. This produces a heat load on buildings, resulting in loss of comfort or an increase in electricity bills and greenhouse gas emissions for air-conditioning.

The main approaches used individually or in combination are to;

- select pigments to match visible colours using pigments that also naturally reflect more infra-red radiation,
- utilise hollow silica/ceramic microsphere additives that reflect the longer wavelength solar radiation and
- improve the ability to radiate any heat build-up out to the sky.

Attempts to simplify a complex situation for public consumption means advertising, comments and claims are often made that are technically incorrect. Measurements from some paint suppliers show not only the benefits of the paints but also claims of ‘insulation’ that are unsubstantiated and simply incorrect. Heat conduction through the paint layer actually plays an insignificant role compared to the total solar reflectivity and emissivity with lighter colours providing the best surface temperature reduction. It is also shown that the use of a heat reflective paint instead of a standard paint for a particular (visible) colour reduces the surface temperature. The benefits of heat-reflective paints are generally smaller for lighter colours and very small for pure white. Heat-reflective paints can attract a premium so there is a point where the added costs do not warrant use in moderate climate zones.

It can be concluded that the most cost effective solution for coating roofs of houses against the heat from sunlight is to paint the roof with a high build gloss Vivid White paint. In many cases, this is not practical because of the glare. The next best option is to start with as light as possible a colour and then to use one or another type of heat-reflective paint with high reflectance in the infra-red to minimise the surface temperature increase.

***Keywords* heat-reflective, infra-red, paint, sunlight, surface, temperature**

BODY OF PAPER

Introduction

Heat-reflective paints have been available for fifteen years and are used to reflect the heat component of incident sunlight. They are a radiative barrier minimising surface heating rather than providing an insulating layer that reduces conductive heat flow. These paints can lead to a reduction of exterior surface temperatures, and heat load, on buildings, external electrical and electronic equipment, pipes transporting oil or water; insulated pipes used to transport refrigerated wine from one vat to another, insulated outdoor storage vats and hulls of ships. They are beginning to be used in industrial and architectural applications to give significant cost savings through reduced energy use for temperature control. They could contribute to reduced regional peak electricity generation capacity required for coping with air-conditioning on very hot summer days. They can also reduce greenhouse gas emissions caused by air-conditioning and urban heat islands.

This paper explains how many heat-reflective paints function and reviews some of the advertising material and claims in an area hardly covered in the relevant scientific literature.

Heat-reflective paints reduce the absorption of infra-red radiation at surfaces exposed to sunlight without changing the visible colour. Figure 1 plotted from an MS Excel spreadsheet (Renewable Resource Data Center, viewed 21/10/2010 shows the solar spectrum from 300 nm to 2.5 μm and highlights the portion visible to the human eye representing nearly half of the incident energy, with infra-red being most of the remainder.

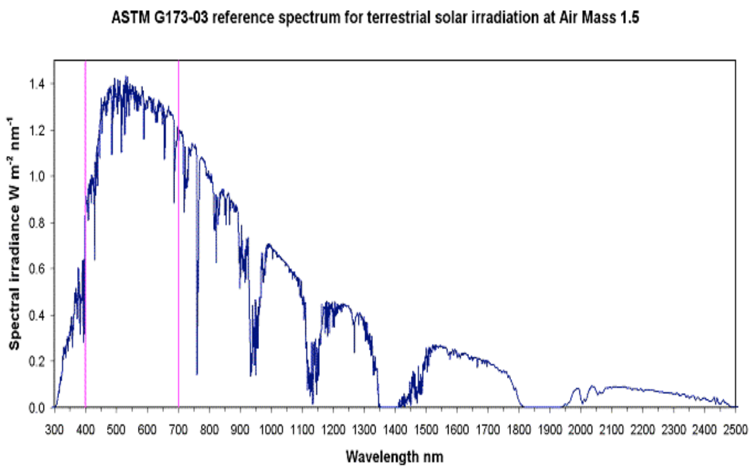


Figure 1 Solar Radiation Spectrum at Sea level showing ultra violet (<400 nm), visible (400 – 700 nm) and infra-red (> 700 nm) components including absorption bands for water, O_2 and CO_2 in the atmosphere. (Data plotted from Renewable Resource Data Center, viewed 21/10/2010.)

Radiation not reflected at various wavelengths across the spectrum is absorbed at the surface, leading to increased surface temperature. That increased surface temperature leads to a heat load on the building resulting in increased temperatures inside or increased energy useage to retain comfortable interior temperatures. It results in a greater stress on thermal insulation systems and also to increased radiaion passing directly through any insulation to the interior. If the reflectance at different wavelengths is weighted according to ASTM G173-03 (2008), the solar spectrum at ground level, a single value of Total Solar Reflectance (TSR) can be derived. Reflected sunlight can be increased by increasing infra-red reflectance, and hence the TSR, without changing the perceived colour. Dark colours will still absorb strongly in the visible region contributing to higher surface temperatures than lighter colours with the same level of infra-red reflectance.

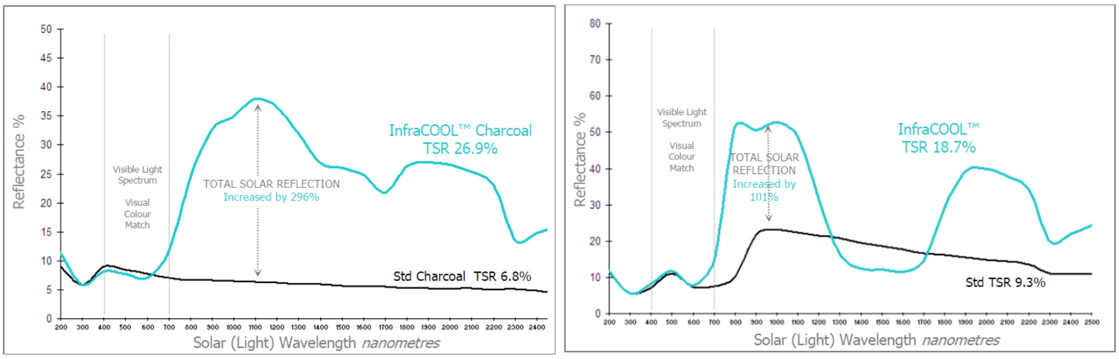
Surface temperatures are a function of the emissivity, a material property that determines the long wavelength infra-red radiation emitted from a surface. An emissivity of unity maximises this radiation, reducing excess surface temperatures. Many materials have an emissivity in the range 0.8 to 0.9 but bright metal roofs become very hot despite high reflectivity because the emissivity is low.

In 1908, Mie published a paper on light scattering from particles approximately the same size as their wavelength (Mie, 1908) which is quite different to the highly wavelength-dependant Rayleigh scattering from molecules in the atmosphere that lead to the sky's characteristic blue colour. Mie scattering depends upon the difference in refractive index (RI) of the scattering particle from the medium that light is traversing, the diameter of the scatterer and, to a certain extent, the wavelength of the light. From each Mie scattering there will be a range of angles where light is scattered and some will be scattered in a backwards direction.

An example of particles having higher RI than the medium is given with clouds. White light can be seen scattered out of the cloud from multiple water droplets or ice particles. It allows us to see the total volume of the cloud where there are Mie scatterers. Milk is another example with an oil-based emulsion in a water-based bulk. Light coloured paints with high reflectance in the visible spectrum have TiO_2 particles with high refractive index that also scatter infra-red light reasonably well.

In a standard paint formulation with 1 μm TiO_2 particles there will be approximately 11 percent backscattering efficiency at 450 nm (blue light) reducing to 1.6 percent at 2 μm infra-red wavelengths. Doubling the TiO_2 particle size boosts the infra-red backscattering at 2 μm wavelength to 4.4 percent (Prahl, viewed 17/6/2010).

It is also possible to select coloured pigments that have absorption in the visible spectrum giving their visible colour but with high RI in the infra-red and little absorption, allowing them to reflect much of the infra-red. It is also possible, as seen in Figures 2 & 3, to even create black paints and near black paints with judicious use of combined 'infra-red' pigments that absorb across the visible. This is done whilst reflecting moderately well in the infra-red instead of absorbing right across the spectrum like traditional paints based on carbon black pigment. An example of an Australian company with this approach is the Dulux/AcraTex range of InfraCOOL paints (Dulux, viewed 21/10/2010).



Figures 2 & 3 Standard Dulux and InfraCOOL Charcoal and Mid Brunswick Green paints demonstrating how pigment selection can lead to enhanced infra-red reflection. (test reports at Dulux, viewed 22/10/2010.)

An alternative situation, not often considered for Mie scattering, occurs when the RI of the 'particle' is less than that of the medium. Figure 4 provides an example of this, where microscopic air bubbles are entrained in water. We can see through the water to the milky volume, where the small underwater bubbles are reflecting ambient light towards the viewer. Similarly, studies have been made of light scattering from small bubbles in water-based bioreactors (Berberoglu *et al*, 2007). These examples with water are similar to the effect achieved in the infra-red for paints that include hollow microspheres with the paint medium as the bulk material.

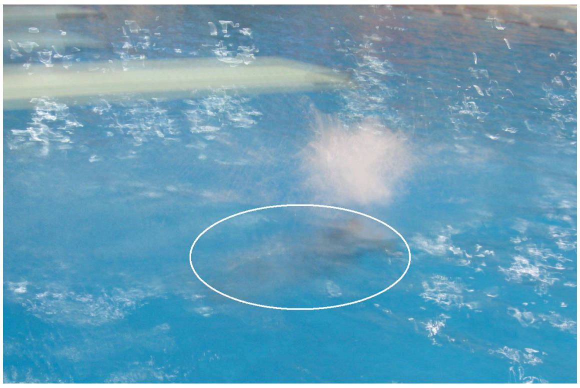


Figure 4 Highlighted milkiness obscuring the diver beneath her entry point in the water, is caused by Mie scattering of fine air bubbles reflecting ambient light. The medium has a refractive index of 1.3 and the bubbles a refractive index close to 1.0.

One approach for creating a heat-reflective paint is to add hollow microspheres that do not scatter light in the visible spectrum but scatter effectively in the infra-red region (Dombrovsky, 2005), (Dombrovsky, *et al*, 2005), (Dombrovsky, *et al*, 2007). In the US, there are several companies producing hollow microspheres including INSULADD, Hy-Tech and 3M. The first two of these are spinoff companies from NASA projects but have no relationship to the technologies and mechanisms for space shuttle tiles. In Australia, the microsphere additives appear to be dominated by INSULADD and Thermilate which both come from the same source. An example of a company using the INSULADD/Thermilate approach in Adelaide is Acryloc's additive products (Acryloc, viewed 20/10/2010) plus their roof formulations (Acryloc, viewed 19/10/2010). Acryloc imply in their documentation that they combine the 'infra-red pigment' approach with the microspheres for their tinted colour formulations.

Another approach is to formulate the paint combining one or both of the above two methods while making sure that emissivity is high in the 8 to 13 μm wavelength region. There is a transmission window in the atmosphere that is relatively independent of the moisture level such that heat can effectively be removed from the surface, and even the whole building, by radiative transfer processes. The broad peak for black body radiation at surface temperatures between –10 °C and +100 °C lies in this region and extends from wavelengths of 3 μm to 40 μm. An example of an Australian company that uses this approach is SkyCool. (SkyCool, viewed 24/05/2010), (Wojtysiak, 2002). SkyCool is a highly reflective white paint combined with a claimed high emissivity of 0.94. This is claimed to have reduced air-conditioning costs in a southern Queensland supermarket by 40% p.a. (Davidson, 2004) but in cooler climates would increase winter heating. The Wojtysiac patent above only refers to selective emissivity in the 8 to 13 μm region achieved, at least in part, with hollow microspheres but does not describe the mechanisms for enhancing emissivity. It is known that at least one other heat-reflective paint manufacturer chemically formulates the paint medium to enhance emissivity.

ASTEC, who produce the Energy Star range of paints (ASTEC, viewed 19/10/2010), will not divulge the technical approach they take for IP reasons but claim (ASTEC, 2010) that it is a radically different approach in optimising IR reflectance to the above methods.

Heat-reflective paints rely on maximising reflection of the whole solar spectrum at the surface. This requires minimising any absorption and therefore any contaminants trapped at the surface that absorb the solar radiation. A gloss surface will more likely have contaminants washed off by rain or blown away than for a matte or low-sheen paint that can trap absorbing particles in surface crevices over time and lower solar reflectance. Products such as ASTEC's Dirtguard and the Dulux InfraCOOL range, have been chemically formulated to ensure low dirt pickup over an extended period. Generally a thicker layer is required to produce a layer opaque to infra-red radiation because of less efficient scattering at the longer wavelengths. A 'membrane' having a thickness of 150 μm or more would typically be required for a heat-reflective paint.

Advertising

It is difficult to advertise to non-technical people about infra-red, heat radiation as distinct from heat conduction and, in particular, about effects that are dependent upon emissivity. As a result, the advertising explanations are often not technically correct as to how these paints function.

Much of the advertising for paints with hollow microspheres incorrectly state or imply that the paints function as an insulating layer (Hy-Tech, viewed 20/10/2010) with the hollow microspheres acting as 'thermos bottle'-like cells (Hy-Tech, viewed 21/10/2010) with empty interstitial volumes. A similar idea is found in cartoons for INSULADD (INSULADD, viewed 20/10/2010). Paint layers containing more than 40 percent total volume of pigments and microspheres would have insufficient cohesion to be a viable layer against abrasion and would not provide corrosion protection. The thermal conductivity through a thin membrane made of microspheres, pigment particles and paint medium will be almost identical to that of a similar thickness of a layer without the microspheres. Even high quality thermal insulation batts which are almost entirely made of void require 50 to 150 mm thickness to achieve good thermal insulation. The heat reflecting paint layers have only a small proportion of voids and are usually well under 1 mm in thickness. It is not possible for a properly formulated heat reflective paint containing hollow microspheres and forming a cohesive, integral layer of less than 1 mm thick to act as an effective thermal insulator. Despite advertising material to the contrary, thermal conduction plays an insignificant role compared with the importance of Total Solar Reflectance and emissivity in minimising temperature build-up.

The Australian-based Heat Reflective Paints website (Heat Reflective Paints, viewed 21/10/2010) provides some information about brands such as ASTEC, DuroBond, NuTech, ShieldCoat and SolaCoat. The website expresses disappointment in the way some of the paints and additives are marketed with such technical inaccuracies.

Comparisons with conventional paints

Reflectance spectra given in advertising with any resulting TSRs and temperature increases calculated to the ASTM E903/C-1549 standards should be able to be trusted. Specific temperature differentials where the paint company has done correctly instrumented tests under outdoor conditions may well provide useful comparisons but tests done under infra-red lamps will grossly exaggerate the benefits of heat reflective paints. Generalised advertising claims by manufacturers that their paint will lower room temperatures by a given number of degrees should be ignored because of the complexities involved.

INSULADD provide comparisons as seen in Figure 5 (INSULADD, viewed 21/10/2010). They show lower surface temperatures of INSULADD white paint compared with other paints and materials for Central Texas in August (Summer) with an ambient of 33 °C in clear sunlight. These tests clearly demonstrate the benefits of the white, heat-reflective paint over the other alternatives for the particular testing regime chosen.

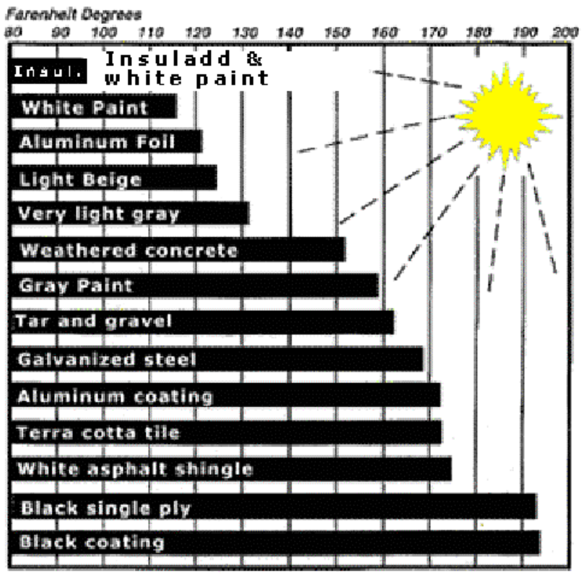


Figure 5 Temperatures (°F) of coatings and other materials in August sunlight conditions in Central Texas in at an ambient of 90 °F (33 °C) and a clear sky (from INSULADD, viewed 21/10/2010).

In Figure 6, is shown the reflectance comparison by ASTEC of a conventional black paint with their Energy Star Black (ASTEC, viewed 19/10/2010). Whilst there are large infra-red reflectance gains at wavelengths over 1000 nm, it should be remembered from Figure 1 that there is a major part of the incident infra-red from sunlight between 700 nm and 1000 nm. A truly effective heat-reflective black paint would rise sharply in reflectance to high values at wavelengths very close to 700 nm with greater TSR effect.

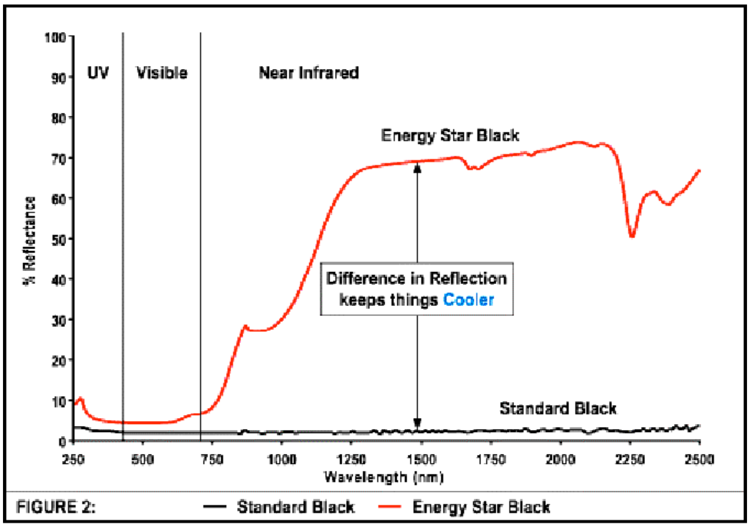


Figure 6 ASTEC comparison of their heat reflective Energy Star Black with a standard black paint demonstrating substantially increased infra-red reflectance at wavelengths above 1000 nm (ASTEC, viewed 19/10/2010).

A comparison of reflectance for conventional and heat-reflective Off White paint from ASTEC data (ASTEC, viewed 19/10/2010) is portrayed in Figure 7. This shows less advantage in infra-red reflectance for Energy Star paint over standard paint when compared with Figure 6 for a black colour. Between 90 and 95 percent of pigment in a standard off-white colour will be TiO_2 and that already scatters strongly in the infra-red, leaving less room for improvement in infra-red reflectance when using Energy Star paint.

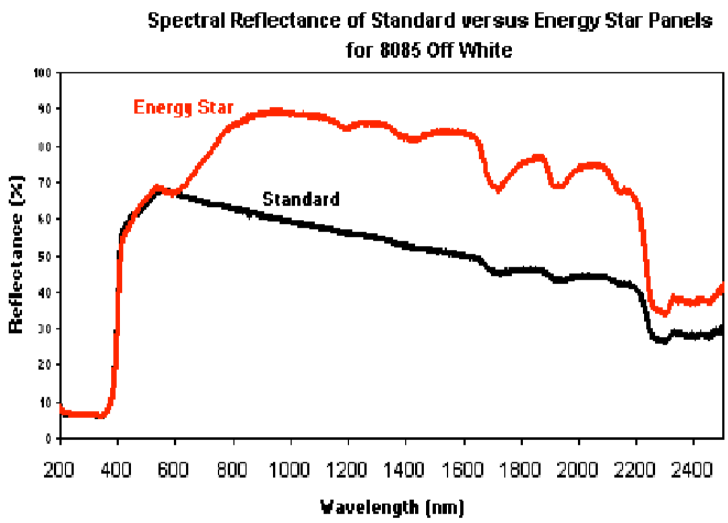


Figure 7 ASTEC comparison of their heat reflective Energy Star Off White with a standard off white paint demonstrating substantially increased infra-red reflectance at wavelengths over 800 nm.

Information on TSRs to ASTM C-1549 was plotted from ASTEC's data (ASTEC, viewed 20/10/2010) and is shown in Figure 8. It demonstrates that TSRs can be improved by up to 31 percent for dark colours reducing to 4 percent for pure white.

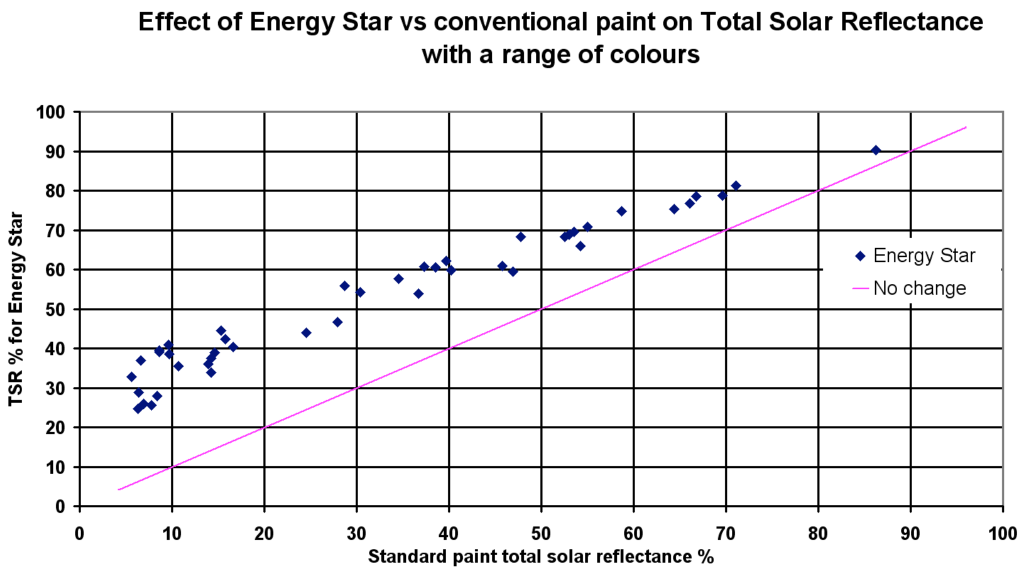


Figure 8 Comparisons between heat reflective and conventional paints compiled from ASTEC data (ASTEC, viewed 19/10/2010) and graphed with MS Excel. These show increased TSR for Energy Star versions of the same colours.

Some of the colours in the ASTEC website material also had information about surface temperatures in sunlight where surface temperatures are calculated to ASTM E903/C1549 for low wind conditions. Low wind conditions are chosen because these are the worst conditions for heat buildup and often very hot days have low wind conditions. Dulux/AcraTex had similar information available to ASTM C-1549 based on their TSRs for standard Dulux and their InfraCOOL paints so these can be directly compared with the ASTEC data. Plots were made in MS Excel for the conventional and heat-reflective versions of colours from the data available from both companies. These are presented in Figure 9 and provide an interesting insight into the importance of TSR to the surface temperatures in sunlight according to the ASTM calculations. The plotted data based on ASTM calculations for low wind conditions directly show that the higher the TSR, the lower the surface temperature is. They also show clearly that there is very little difference between conventional and heat-reflective paints in terms of surface temperature once TSR is taken into account. The major factor affecting surface temperature is the TSR, with emissivity being of lesser importance.

Unfortunately there was no data available from Acryloc or SkyCool on TSR data and resulting temperature rises calculated to the relevant ASTM standards. These products incorporated hollow microspheres.

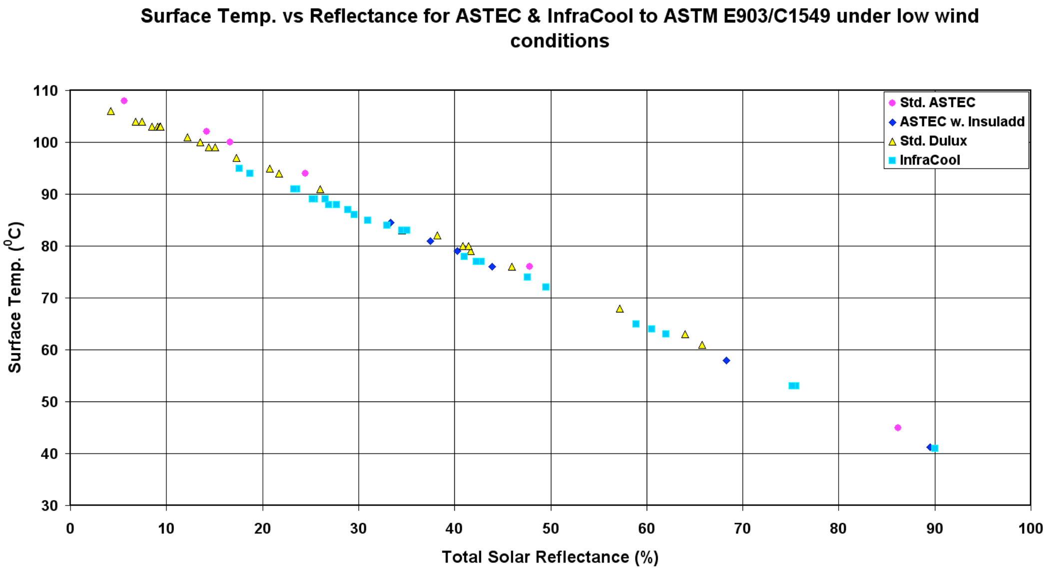


Figure 9 Demonstrating the direct influence of TSR with various colours on the surface temperature and the relatively small effect of whether the paint was a heat reflective or a conventional one and based on ASTM C-1549 low wind calculations. This graph was plotted from ASTEC and Dulux data.

Amongst the Dulux standard and InfraCOOL paints (without microspheres) there is a slight difference with standard paints a degree or so higher in temperature, most likely due to the lower emissivity of standard paints at 0.85 as compared with 0.9 for the InfraCOOL which has been formulated to better emit absorbed heat. The ASTEC heat-reflective paints with emissivity of 0.88 fall between both Dulux paint types in temperature rises. ASTEC heat-reflective white performs nearly to the same as the InfraCOOL white.

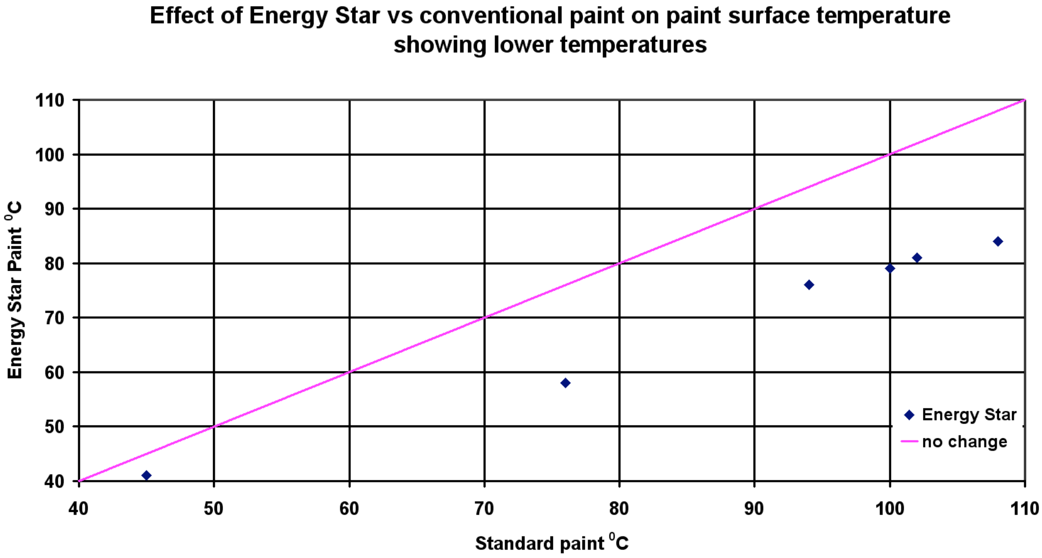


Figure 10 Reductions in surface temperature for a range of colours as plotted from ASTEC data based on the ASTM calculations.

The effect of reducing surface temperature for heat reflective paints is shown in Figure 10, which compares ASTEC temperature data for a range of coloured paints in standard and Energy Star paints as calculated by ASTM methods. The effect is smaller (4 °C) for pure white paint than for darker coloured paints (24 °C). This raises the question as to the benefits gained for the added expense in opting for heat-reflective white paint.

In Table 1 (scanned from Acryloc brochure, 2008), Acryloc provide surface temperature reductions in a Roofcote brochure comparing their heat-reflective Roofcote (with Thermilate) to their standard equivalents of the same nominal colour when placed under infra-red lamps. These lamps do *not* reproduce the solar spectrum and exaggerate the temperature differences compared with summer sunlight or lamps correctly simulating the solar spectrum (and having an intensity of 1 kW/m^2.at the test sample). Temperature differences in sunlight would be much less since half the energy in sunlight is in the visible part of the spectrum and the two versions of the same 'colour' will be absorbing the same amount of energy in the visible region. ASTEC (ASTEC, viewed 21/10/2010) presents an Amdel report, 05MAAD10444 Part 1, that gives surface temperatures from 41 to 90 °C under low wind conditions and an ambient of 27 °C calculated for ASTM E1980-01. If this is compared with Acryloc's extreme temperatures of 81 to 136 °C for their heat-reflective paints under infra-red lamps, then the overall trends are similar to ASTEC data but the magnitude is exaggerated. Darker colours, in both cases, will benefit much more than lighter ones from the use of the infra-red reflecting paints but they come from an unfavourable starting point. They are also similar in that pure white heat reflective paint will only provide a slight benefit to using a conventional white paint.

Table 1 Acryloc comparison of surface temperatures with the heat reflective Roofcote products based on Thermilate compared with Acryloc's standard products under infra-red lamps. The effects under sunlight would not be as good.

Colour	Cooler than CRC Equiv by
Arctic White	3°
Blue Ridge	16°
Brunswick Green	-
Bushland	
Charcoal	22°
Classic Cream	13°
Cottage Green	40°
Deep Ocean	15°
Dune	
Headland	15°
Ironstone	39°
Jasper	37°
Manor Red	19°
Night Sky	36°
Pale Eucalypt	
Paperbark	25°
Plantation	28°
Sandbank	29
Shale Grey	26°
Sienna Clay	14°
Stone	29°
Surfmist	
Wheat	31°
Wilderness	27°
Windspray	29°
Woodland Grey	17°

Cost Implications

Using a heat-reflective paint does come at a cost premium to a conventional paint. For example, in Adelaide in 2008, the quote for high pressure water cleaning of 50 m^2 of a weathered, galvanised iron roof followed by priming and two coats of Vivid White gloss acrylic paint was $1000 whilst the same process with topcoats of Acryloc heat-reflective paint using Thermilate was $1400 using the same contractor. There was a similar differential with ASTEC heat-reflective paint. The additional cost to a $3000 professional job in painting a 180 m^2 house roof with Dulux InfraCOOL rather than standard paint would be $500 to $1000.

The cost differential for critical industrial applications, where there are aesthetic or local government colour restraints or for extreme climates such as Darwin, or elsewhere in far northern Australia, may well make it worth while to opt for the more expensive heat-reflective paint option.

Conclusions and recommendations

Advertising of heat-reflective paints often refers to insulation properties; however, restricting heat flow through paint films is not a significant part of the benefits of heat reflective paints. The predominant factor reducing solar heat load on buildings etc. is the Total Solar Reflectance of the exterior surface and not thermal conductivity, but emissivity does play a small role. There is a lack of technical accuracy in much advertising material.

The most cost effective solution for non-critical applications is using two coats, for infra-red opacity, of a conventional gloss white acrylic paint over an appropriate primer to reflect heat and reduce the heat load from sunlight. Gloss paint is recommended to minimise dust and dirt collection. It is preferable to spray the gloss paint wet to attain the smoothest surface possible that will not quickly capture dirt and dust.

If the application is critical, such as coatings over insulation around piping carrying refrigerated fluids, or in extremely hot climates, then optimal solar heat reflection can be attained with a heat-reflective version of a pure white paint.

If architectural or aesthetic reasons eliminate the use of a pure white paint because of the glare, then as light as possible coloured paint should be used. The paint should be heat-reflective to ensure that as much infra-red as possible is reflected at the surface and reduce the heat load on buildings and pipework.

References

Acryloc, viewed 19/10/2010, *Acryloc Roofcote Supa Cool incorporating Thermilate,* <http://www.acryloc.com.au/cgi-bin/products.cgi?category=%22Roof%20Membranes%22>.

Acryloc, viewed 20/10/2010 *Thermilate Additive Pack,* <http://www.acryloc.com.au/cgi-bin/image_popup.cgi?image_name=/products/images/16100.jpg>.

ASTEC, 2010, personal telephone discussion with the Managing Director, Mr. Mark Waters .

ASTEC, viewed 19/10/2010, *How do They Work ?,* <www.astecpaints.com.au/energystar/how_do_they_work.htm>.

ASTEC, viewed 21/10/2010, *Slar Reflectance Index Test Reports – Energy Star EC-100 Dirtguard,* .< http://www.astecpaints.com.au/energystar/downloads/sri/ec100_dirtguard.pdf >.

ASTEC, viewed 20/10/2010, *TSR Test Reports to ASTM C-1549„* <via www.astecpaints.com.au/energystar/about_energystar.htm >.

ASTM G173-03, (2008), *Reference Solar Spectral Irradiance: Air Mass 1.5,* American Society for Testing and Materials.

Berberoglu H, Yin J, Pilon L. (2007) *Light transfer in bubble sparged photobioreactors for H_2 production and CO_2 mitigation* Peer Reviewed, Permalink <http://escholarship.org/uc/item/4g62323h>.

Davidson S. (2004) *SkyCool – extraordinary paint on a hot tin roof,* ECOS (CSIRO publication), Issue **119**, Apr-Jun 2004, p. 12

Dombrovsky L. (2005), *Modeling of Thermal Radiation of Polymer Coating Containing Hollow Microspheres* High Temperature. Vol. **43**, No. 2, pp. 247–258. Translated from Teplofizika Vysokikh Temperatur, Vol. **43**, No. 2, 2005, pp. 256–266.

Dombrovsky L., Randrianalisoa J. Baillis D. Pilon L. (2005) *Use of Mie theory to analyze experimental data to identify infrared properties of fused quartz containing bubbles.* <http://www.escholarship.org/uc/item/96w8k08s> Peer Reviewed Permalink.

Dombrovsky L. Randrianalisoa J. & Baillis D. (2007) *Infrared radiative properties of polymer coatings containing hollow microspheres* International Journal of Heat and Mass Transfer **50** 1516–1527

Dulux, viewed 21/10/2010 *Dulux AcraTex 962 Cool Roof,* <http://www.dulux.com.au/specifier/our-brands/dulux-acratex/products/roof-restoration/high-build-membrane/product-detail?product=7365>.

Dulux, viewed 22/10/2010, test reports at *InfraCOOL Heat Reflective Coating Technology*, < http://www.dulux.com.au/specifier/our-brands/dulux-acratex/infracool/infracool-information>.

Heat Reflective Paints, viewed 21/10/2010, *Compare Brands*, <http://www.heatreflectivepaints.net.au/Compare-Brands>.

Hy-Tech, viewed 20/10/2010 *How Ceramic Paint Saves Energy*, <http://www.ceramicadditive.com/conduction_heat.html>.

Hy-Tech, viewed 21/10/2010, *Insulating Ceramic Microspheres What they are and how they make paint Insulate,* <http://www.ceramicadditive.com/work.html>.

INSULADD, viewed 21/10/2010, *How It Works,* <http://www.insuladd.com/howitworks.html>.

INSULADD, viewed 20/10/2010, cartoon in *History,* <http://www.insuladd.com/insulating-paint-history.html>.

Mie G., (1908) *Beiträger zur Optiek trüber Medien, speziell kolloidaler Metallösungen* Annalen der Physik Vierte Volge 25, 3, 377-445 in German and translated to English by Crossland, Barbara in 1976 to *Contributions to The Optics of Turbid Media, Particularly of Colloidal Metal Solutions* for the Royal Aircraft Establishment Library

Prahl, viewed 17/6/2010, *Mie Scattering Calculator* with 1 μm TiO_2 particles of RI =2.68 in medium of RI=1.5 calculated at <http:// omlc.ogi.edu/calc/mie_calc.html>.

Renewable Resource Data Center, viewed 21/10/2010 *Reference Solar Spectral Irradiance: Air Mass 1.5 – downloaded MS Excel spreadsheet,* <http://rredc.nrel.gov/solar/spectra/am1.5/>.

SkyCool, viewed 24/5/2010 , *SkyCool - In the business of Cooling Buildings,* <http://www.skycool.com.au/>.

Wojtysiak C. S., (2002) *Radiative cooling surface coatings.* Australian Patent Application no. 20023002117.

BRIEF BIOGRAPHY OF PRESENTER

John Pockett has had a broad career mainly in industrial R&D, process/product improvements and data analysis across a range of industries, leading-edge technologies and working across engineering and scientific disciplines. He has worked in areas such as paint, medical equipment, electronics, ophthalmic, laser, printing, photovoltaics, electrophotography and biofuels. He has had practical experience in independent research. Innovations have led, amongst other things, to patented IP and IP utilised as Trade Secrets. He has been employed in organisations such as Dulux, Optische

Industrie, Philips, Adelaide University, SOLA Optical, Research Labs of Australia, Uni. of SA, Flinders Uni, and carried out consultancy work in John Pockett & Associates. His original BSc in Physics and Maths was supplemented in recent years by a PhD in Materials Science (Polymer Chemistry) on a part-time/full-time basis whilst continuing with his consultancy work.

In the last three years, he has also played a part-time role in University of South Australia's Sustainable Energy Centre as an Adjunct Senior Research Fellow working on projects with other researchers and students. These projects include retrofitting vehicles to make them hybrids, phase change materials, roof insulation, radiative cooling and heat-reflective paints.

He is a Fellow of the Australian Institute of Physics, a Chartered Chemist member of the Royal Australian Chemistry Institute, a member of the SA Committee for the Australian Solar Energy Society, a member of the Organising Committee for the recent Chemeca2010 conference and is currently Chair of the Joint Chemical Engineering Committee in SA.