

The cool solution to a hot topic: thermal coatings

As energy costs rise, thermal coatings have become a hot topic. New paint formulas can enhance a building's "energy envelope", by moderating energy transfer in and out. Reduced solar radiation (in hot climates) and increased heat conservation (in cold) cuts both cooling and heating costs. James T. Maxted, of Becker Industrial Coatings' Long Term Development Group, explains the multiple benefits of "enhanced functionality".

A properly formulated coil coating system for architectural end-use must be able to perform a variety of functions simultaneously.

The most obvious function is decoration: imparting identity and character to metal facades and roofing. It must also maintain its looks over time – many coil coatings now carry warranties of 20 years or more. In this respect, high durability coatings (that maintain gloss, colour and film integrity), as well as systems that minimise dirt pick-up and improve dirt-shedding properties, are also important.

Another critical function is to protect the galvanised steel building from corrosion. Becker has considerable expertise in the formulation of high-build and flexible primers to maximise corrosion protection, especially at vulnerable points such as bends and the edges of sheets, without recourse to toxic anticorrosive pigments.

But a coil coating can also do more. Suitably formulated, the coating system can also contribute to the building's "energy envelope", by moderating energy transfer in and out of the building. Energy envelope

considerations now form a critical aspect of modern building design, and reduced energy usage in buildings is an especially 'hot topic' in the USA and the Far East.

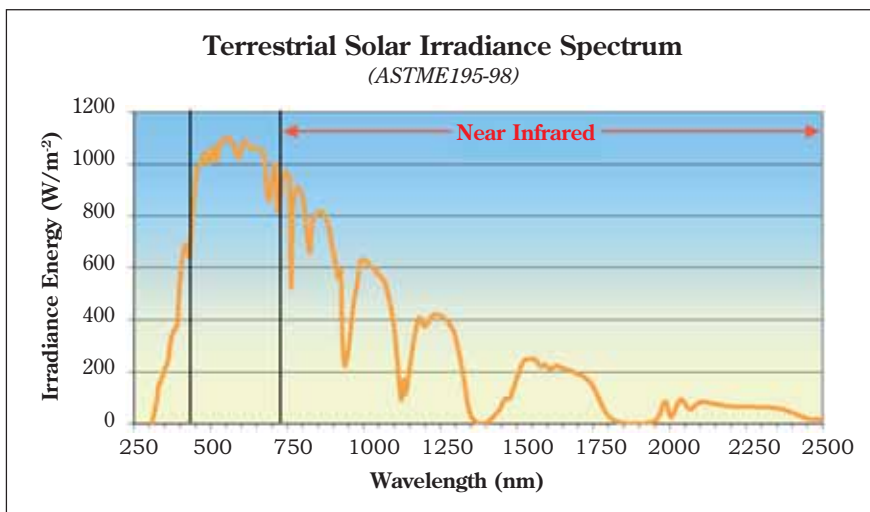
Multiple benefits – health, environmental and economic

Thermal-control coatings benefit both the owner of the building and the environment in general.

For the owner of the building, the greatest incentive to use these coatings is a reduced energy bill. The BeckryTherm system has the potential to cut both air conditioning (AC) and heating costs. In non-conditioned environments, such as animal-rearing units, these coatings can also improve thermal comfort by moderating living-space temperature. US Federal and State codes and financial incentives are now in place, to actively encourage specifiers and owners to use thermal-control coatings.

The environmental considerations are equally important. High usage of fossil fuels – concomitant with increasing use of AC systems – contributes to the problems of global warming, the urban "heat island" effect and smog build-up. As more and more buildings utilise AC in different parts of the world, peak energy demand rises even more during the hottest months of the year. This ri-

Figure 1: Terrestrial solar irradiance spectrum.



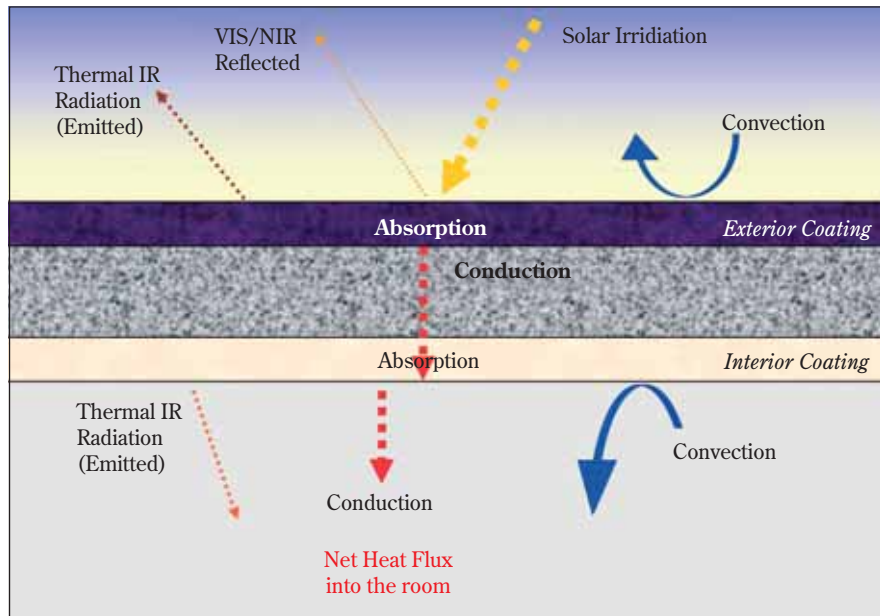


Figure 2: Building energy diagram

ing demand is cause for concern in the USA, Europe and in China. The situation is unlikely to improve in the near future, unless significant steps are taken to reduce energy consumption.

There is every reason, therefore, to seriously consider the benefits of thermal-control coatings, when used for coil-coated cladding.

On the right wavelength – from UV to infrared

Before considering how coatings can properly control energy flow, it is first necessary to understand the type of energy with which coatings act. Figure 1 shows the typical irradiance spectrum of sunlight (taken from ASTM E159-98).

The sun's energy strikes the earth's surface at wavelengths of between 0.3 and 2.5 microns, with differing intensity at each wavelength. Only about 5% of this energy is in the invisible ultraviolet region of the spectrum at ground level. Although small, this is a potentially lethal dose in terms of coating degradation. Actually, a significant proportion of solar energy – about 44% – is in the visible range at ground level. This still means that more than 50% of solar energy is found in the invisible, infrared region. On a hot day, this amounts to a lot of energy that, potentially, can be absorbed by a coat-

ing and transferred to the interior of a building.

But the sun is not the only source of energy in a building. When the heating is turned on inside a building and it becomes warmer inside than outdoors, the net heat flow moves in the opposite direction. Under these circumstances, every object and person in the building acts as if it were a 'small sun' (a grey-body radiator), radiating low-energy heat. This time, however, the energy is not radiated in the UV, visible or near-infrared regions of the electromagnetic spectrum, as in the case of solar energy, but in the mid-infrared region – at wavelengths of between 2.5 and 25 microns.

This means that thermal-control coatings should therefore be formulated to interact with electromagnetic radiation in the UV region from wavelengths of 0.3 microns to those in the mid-infrared region at wavelengths of up to 25 microns.

Electromagnetic radiation: keeping it out – and keeping it in

The diagram in Figure 2 above shows the net heat flux on a hot day into a cooler building interior.

The main source of heat is the sun's energy, acting upon the coated surface of the steel roof. A portion of the sun's energy will be reflected or

scattered in the visible spectrum (giving the colour and gloss of the coating). In the near-infrared region, some of this energy may also be reflected – but with a conventional dark coating much of the energy will be absorbed, resulting in heat build-up in the coating, to temperatures as high as 80°C.

Some of this absorbed solar energy will then be re-emitted by the coating – but now in the form of higher-wavelength, lower-energy radiation in the mid-infrared region of the electromagnetic spectrum. Wind and airflow on the surface of the coating may also influence surface temperature, by convection. Even so, the coating will retain some energy that will be conducted via the metal to the cooler interior of the building.

The interior organic coating will exhibit the same characteristics as the exterior coating, when it meets conducted energy from outside. It first absorbs the energy and then re-emits it to the room's interior as thermal infrared energy. Convection and conduction again play a part in energy transfer to the interior, causing the temperature to rise and making it necessary to turn up the air conditioning.

Clearly, solar reflection is not the only factor to be considered when designing thermal control coatings. Their thermal emittance properties must also be addressed.

Keeping it out...

A correctly formulated exterior paint system should offer the following properties.

- a) Transparency and reflection in the UV region (0.3–0.4 microns)
- b) Absorbance and scattering of light in the visible region (0.4–0.7 microns)
- c) Reflective in the near-infrared region (0.7 to 2.5 microns)
- d) High thermal emittance (2.5 to 25 microns)
- e) Durability

A bright white coating would be the most reflective and thus the coolest option. It reflects 60–70% of all solar energy right across the visible and near infrared as illustrated in Figure 3 above. By contrast, a conventional black coating absorbs all but 5% of total solar energy across the same spectrum. It is easy to understand why white coatings are cool and black coatings hot. But not everyone wants a white roof!

However this does not explain why unpainted metal is often hotter to touch than white painted metal. Although the total solar reflection of both materials is high (65–70% of the solar energy is reflected), the thermal (re)emittance of the absorbed energy in the unpainted metal is very much lower compared with that of the white painted roof (6% and 85% emittance respectively). The unpainted metal simply cannot lose the thermal energy it has absorbed and hence is hotter to the touch. Clearly, we cannot ignore thermal emittance properties.

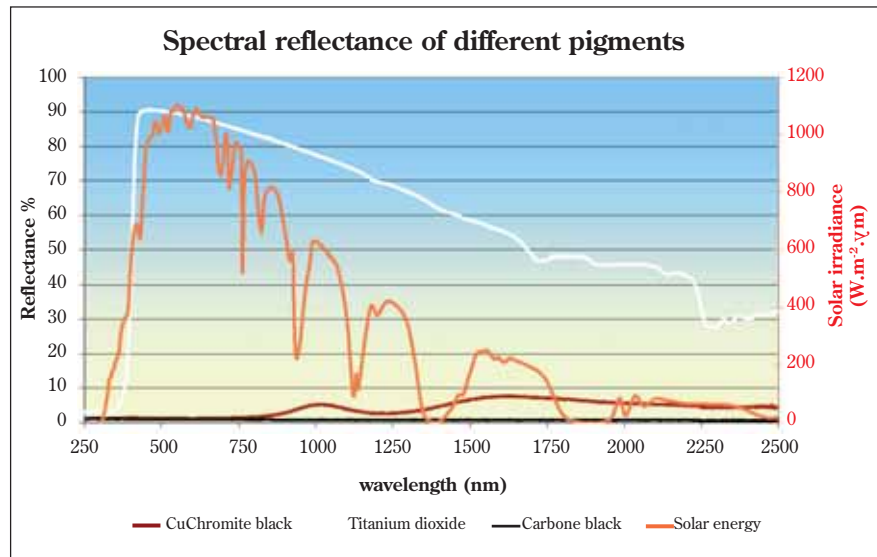
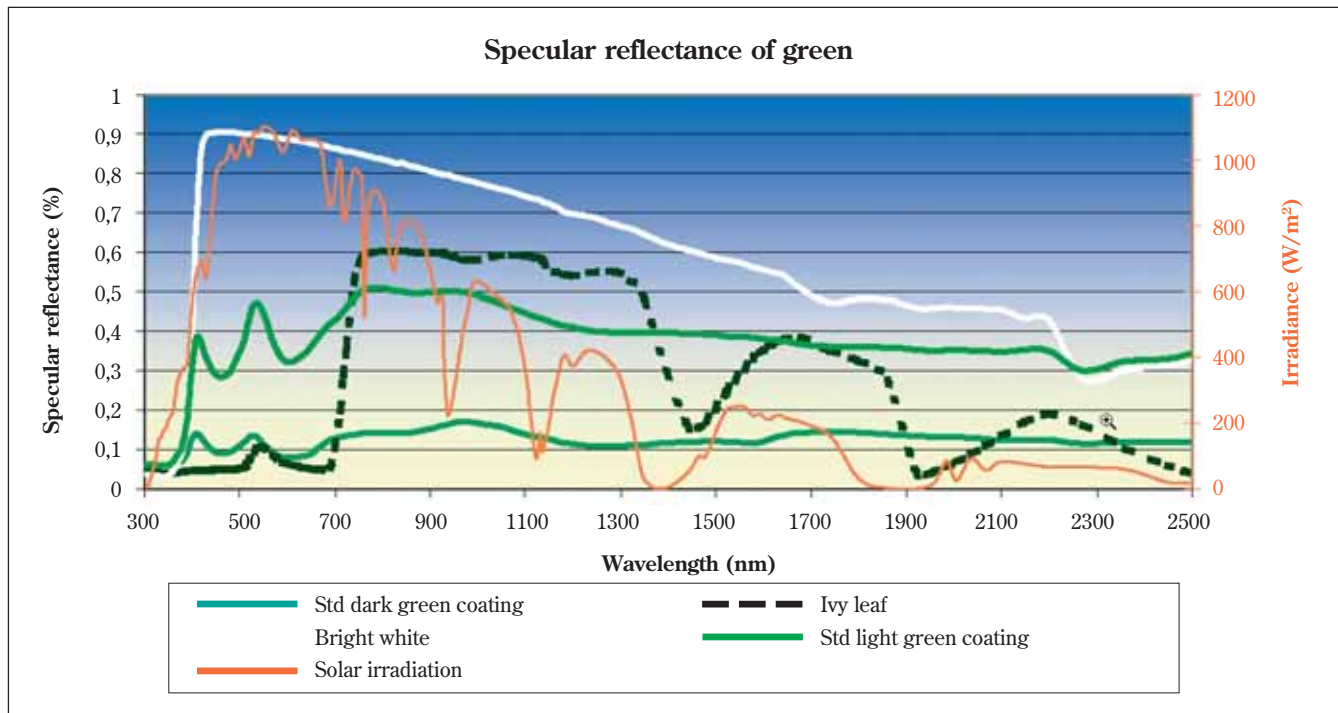


Figure 3: Spectral reflectance of some coil coating pigments.

Neither does this concept explain why a dark green leaf is apparently cool to the touch, whereas a painted steel panel of a similar colour is much hotter. In Figure 4 below, the spectrum of the leaf reveals a very different pattern compared to the dark green coating.

The leaf exhibits a step change in its solar reflectance at 0.7 µm. The

Figure 4: Spectral reflectance of some common materials.



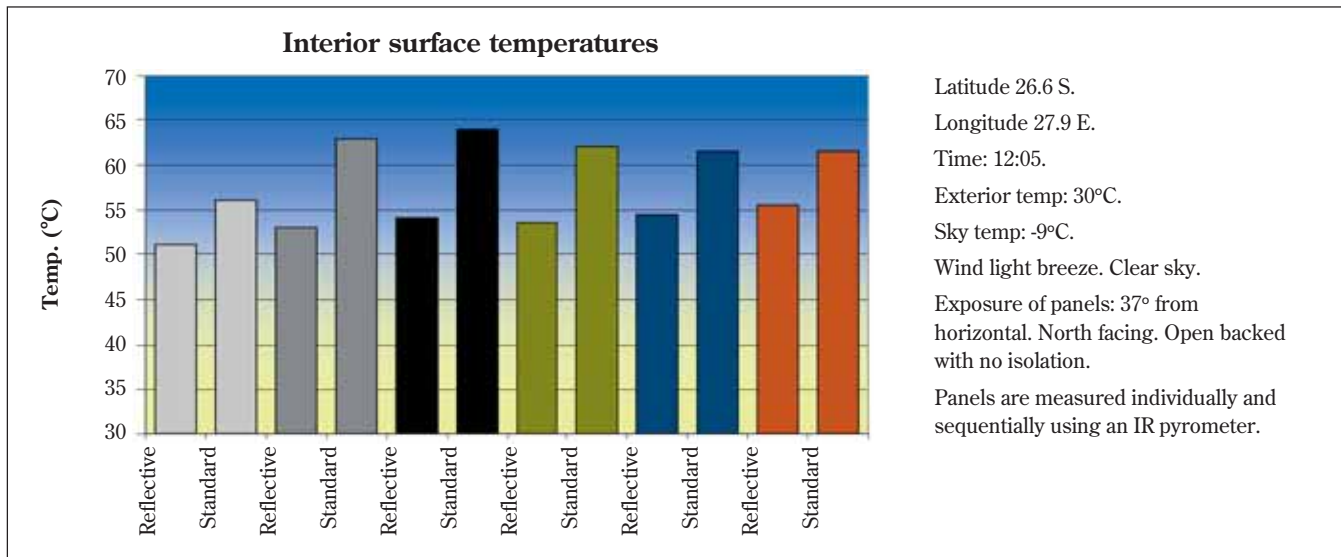


Figure 5: Vereeniging, South Africa, January. 2004.

leaf has the right colour in the visible to enable it to photosynthesize, but it also has the ability to appear “white” in the near infrared and thus be cool enough to avoid cooking! In effect, this is what we want from a cool exterior coating. As always, nature got there first!

...and keeping it in!

Obviously, the properties required by internal and exterior coatings vary somewhat. The energy source is no longer the sun, but the heated steel core of the coil coated material. The paint system needs to be able to reflect this thermal energy back in the direction it came from rather than absorb and then re-emit it in the mid-infrared into the interior of the building. To put it another way, the coating must possess low rather than high emittance in the thermal infrared.

On a cooler day, when the net heat flow is reversed, the interior coating has to function in the opposite manner, now that the room’s interior has become the source of thermal energy. Under such conditions, the coating needs to reflect the radiated thermal energy back into the room, rather than allowing this precious heat to be absorbed into the wall or roof and be conducted out of the building.

To summarise: the low-emissivity coating acts as a thermal energy bar-

rier, blocking a proportion of the thermal energy transfer across the coating. And it has to work equally well on cold as well as hot days.

The challenge has been to formulate an organic coating that functions as a low emitter, since most organic coatings are by their very nature high emitters!

A few degrees can make all the difference...

Given the fact that thermal-control coatings function by controlling energy that is largely invisible, quantifying performance poses some difficulty. Fortunately, many of the confusions of measurement, and some of the spurious claims of early days, can now be avoided – or at least properly evaluated – with the adoption of a number of internationally recognised and standardised (ASTM) methods. The current programmes run within the Cool Roof Community have also been helpful in this respect. The Cool Metal Roofing Coalition, Cool Roof Rating Council and the DOE Energy Star websites contain a lot of useful information.

In Figure 5 above, some real-time test data, measured in the field in South Africa, demonstrates the impressive performance of the Beckry-Therm development system.

The chart shows how the interior surface of the panel is cooled as a

result of using both exterior solar-reflective and interior thermal-reflective coatings together. In this set of six common roofing shades, the BeckryTherm system achieved an average reduction in temperature of nearly 8°C. Of course, this is just a snapshot, and continuous testing in controlled closed systems would be a more rigorous and scientific approach. However, this serves as a simple illustration of the differences we have seen at this location.

A temperature differential of 8°C may not sound much, but it is the difference between a room that is comfortable to work in and one that would force us to switch on the AC. So even a very modest reduction in temperature can have a significant impact on energy consumption.

Hard facts are the best argument

Thermal control is likely to be an important factor in assuring the sustainability and future growth of coil coatings. However, we must be clear about what can and can’t be achieved by manipulating the radiative properties of our coatings. Clear explanations and the relevant use of international standards and protocols, supported by instructive and simply presented demonstrations and real life examples, are vital to ensure the acceptance and proper adoption of this new technology.