Force Curing by Infrared Radiation

Epoxy and polyurethane coatings

Introduction

In many situations there is a need to speed up curing e.g to allow early shipping or fast return to service to minimize down time of a facility. There are various technologies to accelerate the force curing of a coating such as; air movement, convection heat (oven) and infrared radiation, besides addition of catalyst.

This can be done efficiently by heating the uncured coating with infrared (IR) heaters. The heaters may be fixed installation in a production line or mobile units for field repair.

Infrared energy is a form of radiation, which falls between visible light and microwaves in the electromagnetic spectrum (Fig.1).

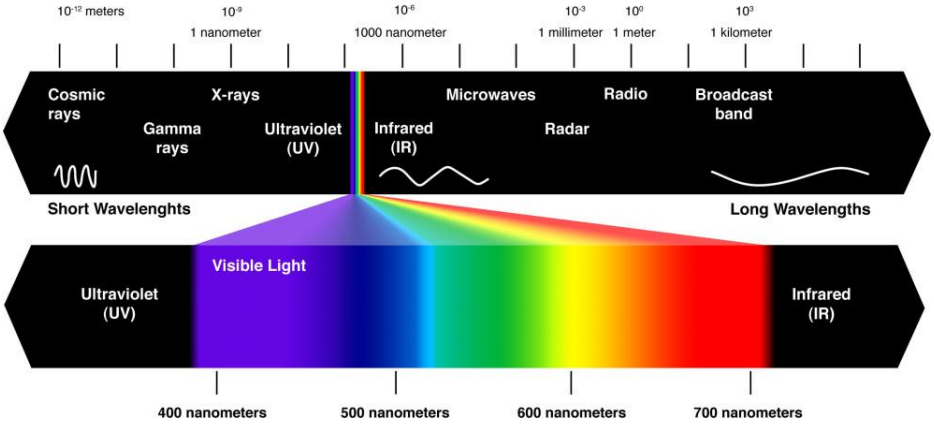

Figure 1: *Electromagnetic Spectrum*

The specific infrared absorption wave length of organic coatings is most efficient between 3 to 10 µm. It is not only the produced heat that accelerates the curing process but also the energy from the specific wavelength that promotes the crosslinking reactions.

Typical benefits

Infrared offers many advantages over convection ovens:

- Increased line speed through-put
- Lower utility costs, less floor space – energy savings
- Enhance crosslinking polymerization and ensures the coating is of optimal hardness, mechanical adhesion and chemical resistance
- Unlike a convection oven the curing process is from the inside out. Curing from the inside out greatly reduces the chance of water or solvent entrapment
- Very precise control compared to convection heat
- Generally the finish is smoother than other curing technologies
- Infrared modules can be portable and adjustable
- Significant reduction of VOC and CO_2 emission observed in gas catalytic IR drying system as IR-panel using the VOC as fuel
- IR introduces less heat into the work environment

Energy level of the IR emitter

Infrared curing is energy radiated directly on the surface by a source (emitter). IR-curing can be carried out by short, medium, or long wavelength IR-radiation (Fig.2).

- Short wavelength IR (from 1µm to 3µm): is characterized by bright visible light which is also emitted. Most of the energy is transmitted through the coating to be absorbed by the substrate. This type of cure is therefore best suited for complex part shapes (non line-of-sight heating) where it is used to heat the substrate. The fastest heat up rate is possible with high energy IR.
- Medium wavelength IR (from 3µm to 8µm): is the most widely used for curing because the energy is absorbed directly by the coating.
- Long wavelength IR (from 8µm to 15µm): is not effective for cure. Much of the energy generated is lost to inefficient convection heating. The fraction of IR energy which does reach the coating is absorbed at the surface, resulting in possible “skin formation” or other defects.

Since long wavelength does little for force curing, the curing process will mainly be carried out by medium and short wavelength. Short wavelength is more intense and is the choice for pre-heating of metal substrate. Depending on the process requirements and design details, an IR curing system might consist of only medium wavelength or a combination of medium and short wavelength.

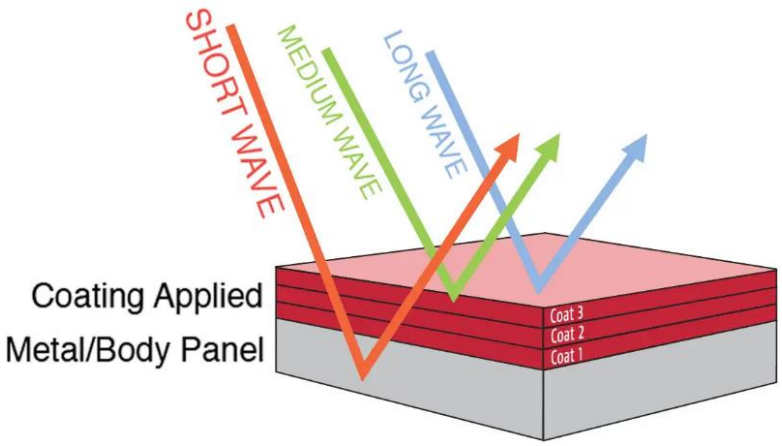

Figure 2: *How infrared curing technology works*[(1)]

Infrared radiation can be generated from both ‘’electric’’ and ‘’gas catalytic’’ sources. Both technologies create heat in the form of infrared energy (IR). The energy produces wavelengths– varying from long, medium, and short. However, the difference between the two depends on these wavelengths. Electric Infrared systems rely on tungsten bulbs to produce a short wavelength of IR. In comparison, gas catalytic systems create a flame-less heat at a medium wavelength.
Electric systems produce a short wave of infrared energy which is more likely to pass through the paint molecules and penetrate the substrate (underlying metal) – causing an unwanted by-product of an over- heated metal panel before the paint is cured.
Gas catalytic equipment uses propane, methane, or a propane/butane mix to produce medium wavelengths. The gas is funneled through the machine and interacts with a catalyst on the inside to produce a “flame-less burning.” By doing so, it sends the heat out across the vehicle and heats the paint equally– all while avoiding heating the metal beneath.

IR-radiation process

If it is required a short period of flash-off can be considered for applied coat before using the IR. Apply IR at an optimum distance and energy output. Thickness of steel influences the curing time, and higher thickness of steel requires more time to heat up the steel and achieve a fully cured coating system. During the IR radiation, coating surface temperature should be closely controlled to avoid sagging of the applied coat on vertical surfaces. When temperature reaches to a level which is close to the melting point of thixotropic agent, sagging is expected. Hempel can advise for product specific temperature limit, or this can be found through experiment.

Vary the time and distance until you achieve the proper homogeneous cure or the surface. Time not temperature is the major factor in determining full cure. A primary approach to determine the degree of curing can be achieved by using a wooden stick, as follows:

- Stage 1: paint is liquid and adhering to stick.
- Stage 2: paint is sticky (like chewing gum) or feels soft when pushing.
- Stage 3 (sufficient heat cycle): Paint is cured, and stick will only leave a tiny scratch.

Depending on the intensity and distance from the IR-radiation source, curing time in the range of is 20 to 45 minutes with medium wavelength is expected.

Table 1 provides some practical data regarding the time that coated object can be handled.

***Table 1**: Practical test – time before object can be handled/Used*

Where tested	Coating system	Specified DFT (µm)	IR Cure
Deck	Hempadur Spray-Guard 35490	3000	45 minutes
Spot repair in-shop	Hempadur 47140/ Hempathane Topcoat 55210	150/50	45 minutes
Repair of tank for drinking water	3 x Hempadur 35560	3 x 125	3x60 minutes
Panels coated in the lab	1 x Hempadur Mastic 45880	1 x 200	30 minutes
Panels coated in the lab	Hempadur Multi-Strength 35840	1 x 750	75 minutes

Hempel has a successful track record of several coating systems which were cured by IR radiation. Figure 3 shows the IR heating unit which was set up for curing Hempathane HS 5561B on a 6-meter tower section.

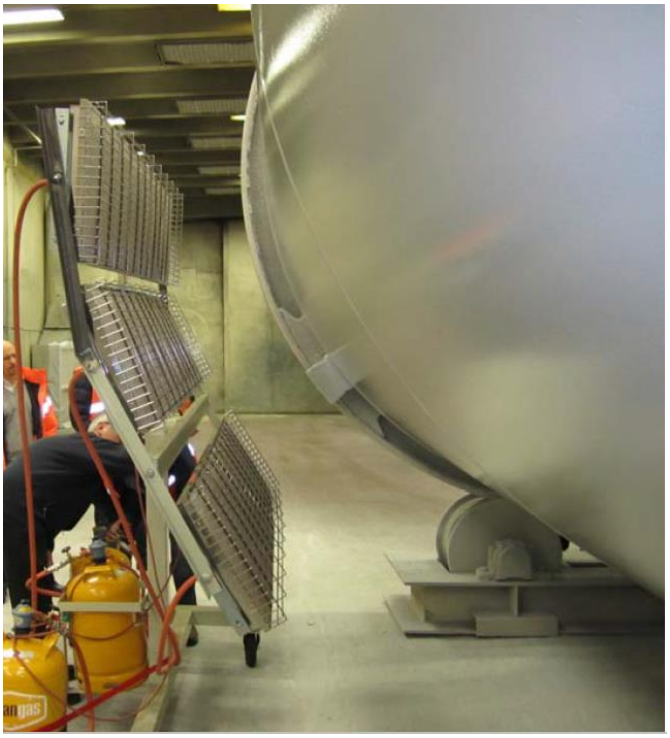

***Figure 3:** Setting up the IR heating unit*

Limitation in using IR-curing process

In following circumstances, it is not recommended to force cure the applied coating system by IR:

- High-build paint with DFT higher than 300 µm and solid volume below 80%: Risk of solvent entrapment, therefore it is recommended to do some test trial in such cases.
- Paint containing wax to be overcoated: Wax may migrate to surface and adhesion for next layer may be compromised if IR is not used for curing process of the second layer
- Physical drying paint: The heat will speed up the drying, but it will not enhance performance.
- Moisture curing products: Some binder types, cure through reaction with moisture in the surrounding air. In such cases, IR-radiation will do little to speed up curing. This is the case for inorganic zinc silicates (Hempel's Galvosil range) and certain polysiloxanes (Hempel's Hempaxane range)

Health and Safety

In general, infrared radiation from the most common sources such as lamps, or from most industrial applications, is harmless for the human body provided the power, distance and duration are appropriate.
Infrared radiation will not penetrate the skin very deeply. Therefore, exposure of the skin to very strong IR may lead to local thermal effects of different severity, and even serious burns.
Short infrared rays are very dangerous for the eyes and long-term exposure may lead to the development of cataract.
Always follow instruction of the provider of the IR-equipment and use suitable protective measures like shielding (eye shields) and protective clothing.

References

1) Global Finishing Solutions. August 30, 2019. Minimal infrared curing integration for maximum results. Minimal Infrared Curing Integration for Maximum Results (globalfinishing.com)