Forced curing & drying

Introduction

Forced curing or drying is the application of an external source of heat to accelerate the transformation from liquid coating film to solid dry film. The transformation may involve evaporation of solvent or water and/or chemical reactions creating cross linking. Heat can be applied to speed up both processes.

Sufficient curing/drying is crucial for the coating system to achieve its required performance e.g. film hardness, block resistance, corrosion protection, chemical resistance, adhesion, and abrasion resistance are achieved only when the coating is fully cured/dried.

Various methods are available to achieve force curing/drying, including:

- Air movement
- Convection heating
- Infrared (IR) heating
- Induction heating

Most industrial forced curing/drying equipment takes the form of an oven, however portable devices are also available for convenience. Among the methods, IR heating provides several advantages over convection heating, such as the ability to cure from the inside out as it penetrates deeper into the coating, requires less floor space, is environmentally friendly and typically has the fastest cure times. Further information and details provided in Hempel's Technical Guideline "Infrared Curing" available on https://www.hempel.com/service-and-support/technical-guidelines.

Convection Curing of Epoxy/Polyurethane coatings

Convention ovens are used in paint shops to reduce minimum overcoating time between layers in multi layer systems as well as to ensure sufficient cure of the last layer to allow transport out of paint shop to storage – whether indoors or outdoors
.
Convection ovens can be batch or pass through (continuous) in design. The oven provides heat through the air and in the early stage, the heat is transferred to the outermost layer of the coating before transferring the heat sequentially to deeper parts of the coating. Therefore, convection heating will initially speed up curing/drying at the surface and may increase the tendency to solvent retention. Flash off of most of the solvent/water before heating in the oven is recommended.

A period of flash-off time (at least 20-25 minutes at substrate temperature of 20°C) and proper ventilation should be considered for solvent-based coatings prior to forced curing, specifically for high-build systems, because high solvent concentration in the air will block solvent evaporation from paint film and may cause paint film defects such as insufficient curing, solvent entrapment and amine blushing. The minimum time required before for forced curing will depend on several factors such as air temperature, air-flow rate and substrate temperature.

It should be taken into consideration that the steel temperature is more important than the air temperature. A 1-mm panel reaches the air temperature very fast, but for a massive steel construction it takes more time to reach the desired temperature and temperature may be uneven on complex structures and it is important to maintain a uniform heat distribution.

Typically, force curing of Epoxy and Polyurethane coatings is done at 45-60°C oven temperature. At temperatures above 60°C, there is no practical overcoating interval and the required DFT should be built in one process.

Maximum steel temperature should not go higher than 35-40°C. Otherwise, more time is needed to cool down the substrate before starting the application of the next coat, and the whole process will not be energy-efficient. For cosmetically high demand clear coat, it is recommended to keep substrate temperature below 30°C.

An increase of gloss can happen in the oven typically, as the binder can move to the surface together with the solvents.

At room temperature, as a rule of thumb, every 10ºC increase, will cut the drying time in half. In forced air-drying, the results of dry to handle may vary from case to case, depending on application and curing conditions. It should be tested to know what the real value is, some parameters will affect the result are as follows:

- Specified DFT
- The thickness of steel (piece mass)
- The steel temperature when entering the oven
- The oven temperature
- Steel surface temperature
- Flash-off time

Most of the time, fine tuning is required on site (due to particular manufacturing conditions). Table 1 provides some practical data regarding the time that coated object can be handled/used.

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

Coating system	Specified DFT	Temperature	Note
Hempel's HS Gas Pipe Coating 87831	80 µm	90°C (Oven) 70°C (Steel)	It goes into an oven after a period at room temperature (Typically the steel is also warm during application e.g. 35°C). As considerable amount of solvent is evaporated during flash-off, the risk for sagging is quite low (slightly different in comparison with Solvent free epoxy).
Hempel's Polyenamel 55102		40°C	Duration: 2-2.5 hr
Hempel's Polyenamel 55102		60°C	Duration: 1 hr
Container Coating systems			
Solvent-borne zinc primer (1536C，17360)	30-40 µm	40-50°C	Duration: 15-30 min
Solvent-born midcoat (1530C，4520C)	40-50 µm	40-50°C	Duration: 15-30 min
Solvent-borne topcoat (5643C，55210)	40-50 µm	70-90°C	Duration: 30-45 min
Water-born zinc primer (1836C)	30-40 µm	50-60°C	Duration: 15-30 min
Water-borne midcoat (18300, 48200, 18450)	40-50 µm	50-60°C	Duration: 15-30 min
Water-borne topcoat (58000, 58041, 58581)	40-50 µm	60-80°C	Duration: 40-60 min

Force curing of products which cure through reaction with humidity

The binder of some products e.g., Hempel's silicate (Galvosil range) and silicone coatings will be crosslinked through reaction with humidity. Thus, the main mechanism to promote curing will be to increase humidity. Increasing the temperature alone will not be efficient, unless the absolute humidity also goes up. At the same level of relative humidity, higher temperature will have higher absolute humidity and thus curing process will be accelerated.

Force drying of cellulosic passive fire protection

Hempel has several experiences with drying intumescent coatings at 40°C (chamber temperature). When force drying is considered, it is recommended to give the intumescent coating a flash off time for at least 8 hours (preferably 12h) to release most of the solvents prior putting an intumescent coating at 40°C, this should be carried out prior to topcoat application. If intumescent coating systems are already top-coated and receive force drying there is significant risk of blistering.

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