Cure Schedules for Moisture-Cure Conformal Coatings

There has been confusion about optimal cure conditions for moisture-cure conformal coatings. This has frequently had to do with cure speed optimization efforts for much thicker bondline adhesives, sealants, and caulks. The challenges associated with curing very thin layers of conformal coating emphasize the different chemical reactions that can occur during cure, and the need for unique and specific testing to determine optimal settings.

Moisture-cure conformal coatings undergo a complex set of reactions as they cure. First, the solvent in solvent-containing coating materials must evaporate away. Moisture from the air permeates into the coating and reacts with a titanate catalyst. The resulting intermediate then reacts with the crosslinker and with the polymer. Finally, all of the remaining species complete the crosslinking reaction to form a uniform coating.

Because the first reaction step depends on contact with moisture from the air, the outer layer of the coating will begin to solidify first. A “skin” of cured coating will form as the cure progresses from the outside inward. At this point, the coating can usually be handled and subsequent manufacturing steps can proceed. As the cure reactions proceed through the depth of the coating, the material will completely solidify. Full cure occurs when the material is fully hardened and strong cohesive adhesion has been obtained to the substrate. This generally occurs several minutes later than “skin-over.”

Factors influencing cure speed include:
- Airflow
- Temperature
- Coating thickness
- Humidity

Airflow

For solvent-containing coatings, most of the solvent must evaporate away before the cure can progress. While low heat can accelerate evaporation, it can also cause a cured skin to form too quickly, trapping solvent under it and causing bubbles to form. Good airflow over the coating will maximize the solvent evaporation rate without causing bubbles. Exposing the coating to 10 minutes at room temperature will generally allow the solvent to sufficiently evaporate. Very high airflow rates may cause ripples or waves in the coating. For all coatings, good airflow maximizes contact between the material and moisture in the air to accelerate cure.

Temperature

Cure speeds can be significantly reduced with heat. However, cure temperatures should not exceed 60°C because higher cure temperatures can cause weakness in the coating and can generate bubbles. Cure temperature is the most important factor in reducing cure times, and the fastest cures can be obtained at 60°C.

Coating Thickness

The thicker the coating, the more time it will take to cure at any temperature. Moisture from the air must permeate into the coating. The deeper the moisture must travel, the longer the cure will take. At elevated cure temperatures, coating thickness has much less influence on cure times.

Humidity

While moisture from the air is mandatory for cure to progress, only a very small amount is actually needed. While a high humidity accelerates cure in a very deep coating thickness, excess moisture will actually slow the cure in thin sections. This occurs when the catalyst near the coating surface becomes saturated with moisture and becomes deactivated. This can significantly slow both the skin-over time and the time to full cure. The fastest cures are obtained at low relative humidities. However, some small level of moisture is required for cure. Below about 5 percent relative humidity, cure will slow very significantly. Elevated cure temperatures greatly lessen the effects of humidity on cure speed.

For the fastest cures at a given thickness, parts should be cured at 60°C with no additional humidity added to the oven. Most convection ovens running at 60°C will have a relative humidity close to 10 percent, which is optimal.

Oven residence time should allow for the coating to skin-over so that the parts can be handled, but does not need to
bring the coating to full cure. Complete cure will continue outside the oven, and this procedure will allow for faster part processing. Note that solvents need about 10 minutes at room temperature to evaporate away before exposing a coating to heat.

The graphs below depict the skin-over time of Dow Corning® 3-1953 Conformal Coating as it relates to humidity during cure over a coating thickness from 0.001 to 0.010 inch.

Conclusions

- Increasing temperatures to 60°C greatly reduces cure times
- Decreasing relative humidities reduces cure times
- Relative humidities below about 10 percent greatly increase cure times
- Curing in a standard 60°C convection oven provides the fastest cure times

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