Cured? If Not Why Not?

Any thermal cure process can be affected by either temperature, time at temperature, or in some cases the rate of temperature change. Without any control of a curing process it is possible that the product can experience either under or over cure conditions which will deteriorate the coating quality. Obviously in most situations an under cure condition is feared most by an applicator resulting in poor physical coating characteristics and reduced life expectancy.

Confirmation of cure quality in most situations is performed by physical testing of the product, after the cure schedule has been completed. This approach is time consuming, tedious and at best only highlights problems well after the damage has been caused. Physical tests such as Differential Scanning Calorimetry (DSC), rub, impact and gloss inspection tests may give some feel for the potential cause of cure problems but they often don’t provide sufficient information to allow rapid, accurate corrective action.

Physical tests performed to validate cure performance

- Impact Testing
- Bend Radius Testing
- Scratch Test
- Visual Inspection – Orange Peel, Gloss & Colour
- Solvent Rub Testing

To guarantee finish quality it is necessary to obtain accurate and specific knowledge of the temperatures experienced by a coated product throughout the entire curing process. Each and every coating has a specific cure schedule, quoted using time and temperature values. For a typical Polyester powder coating the cure schedule is 10 minutes at 200°C. To achieve optimum curing of such powder a coated component must be heated to 200°C and held at that temperature for 10 minutes (dwell time).

Employing the cure schedule the critical temperature quoted is component temperature not air or even oven temperature. Your oven controller although providing air temperature at its specific location does not provide any information on the product temperature. Cold spots in the oven can in fact be missed by the controller itself depending on placement. Component temperature must be measured directly and accurately since the heating rate of any component is affected by many factors other than the oven settings, such as product thermal mass, air circulation and oven loading.

To prove that a coated product (powder or other) is experiencing the optimum cure schedule it is essential that a comprehensive temperature history of the component is obtained throughout the entire thermal process. The only means of obtaining such information is to employ in-process temperature profiling as shown in Figure 2.

Figure 2: Thermally protected data logger system which travels through the cure oven collecting temperature data taken from selected locations on the coated product. Profile graph generated by the data logger giving evidence as to the success or failure of the cure against coating suppliers specifications.

Temperature Profiling – the benefits speak for themselves

Historically and still today temperature profiling is employed purely for the basis of product coating quality assurance. With the advancement of information provided by profiling systems there is scope for so much more. The level of information and analysis capability now available has opened many more areas of interest and benefit as summarised below. Information provided is now helping finishing operations improve their operating efficiency and understanding and control of their thermal cure processes.
Quality Assurance
Confirm that all products achieve the required cure schedule to guarantee coating quality. If problems occur which may effect quality identify them immediately.

Process Control
Prove that the cure process is being performed in a controlled repeatable fashion day to day. Utilising Statistical Process Control (SPC) functionality identify possible future problems allowing pro-active preventative action at your convenience.

Process Optimization
Obtain profile information necessary for developing new cure processes accurately and efficiently.

Improved Productivity
Eliminate rejects or rework therefore maximises product throughput and minimises scrap costs.

Improved Efficiency
Use profile data to understand and optimise the operating characteristics of any cure process permitting possible faster line speeds, therefore, product throughput or reduced operating costs (labour/fuel).

Problem Solving
When problems occur identify the cause and location of the problem promptly. Use the profile information to suggest necessary corrective action and prove the success of such action with follow-on profile runs.

Regulatory Compliance
Archive fully traceable and certified temperature profile data and or create hard copy reports to prove to management, customers, coating suppliers (Accredited Applicator Status) or other regulatory bodies (ISO9001) that your process complies with formal operating standards.

Profiling Methodology – know what you are measuring
Despite the ever increasing improvement in technology of profiling systems mistakes can and are made purely because operators aren’t measuring what they think they are measuring. To obtain meaningful data it is essential that careful consideration is paid to the way in which the profile run is performed as discussed below.

Direct Profiling - Temperature measurements are taken directly from a standard coated product as it passes through the normal production cure process. Direct profiling is generally performed where it would be too expensive to use a test piece and where thermocouples can be applied to the product without causing damage to the surface coating. As the method implies thermocouples must be applied quickly and repeatably on a moving conveyerised line. See Figure 3.

Indirect Profiling - Temperature measurements taken from a test piece designed to imitate a standard coated product. The test piece is inserted during the normal production run and is used repeatedly for profiling specifically day after day. Indirect profiling is performed where direct attachment of probes would cause coating damage and incur expensive scrap. Test pieces are generally employed where production is standard day after day (one product line) therefore only one test piece is necessary.

A significant benefit of applying the principles of indirect profiling is that test conditions are consistent run to run. This being the case it is feasible that Statistical Process Control (SPC) analysis can be applied to quality assurance data collected over time. Integrated within Datapaq’s Oven Insight Software is a purpose SPC package which can be used to analyse archived profiles with no need to export data. The SPC function can be applied to any of the standard analyses including Peak Temperature, Time at Temperature and Datapaq Value.

SPC is an ideal way of proving quality control for oven cure operation to customers over an operating period. From a single report process variations can be identified.
and if data is showing a bias (max temperature dropping gradually with time) future problems can be predicted and so prevented.

**BakeCharts – charting your cure performance**

Paint and powder applicators all have their own specific range of parameters they wish to measure from the temperature profile. At the simplest level a single cure schedule is employed checking that the cure time at or above a critical temperature meets the coating suppliers specification. Obviously this over simplifies the cure process as the paint does not only cure at one fixed temperature but the cure time varies with temperature. Many paint suppliers to account for this now supply BakeCharts or graphical cure windows which show from laboratory testing what range of time/temperatures that can be applied to give satisfactory cure. BakeCharts are popularly employed in the automotive industry where operators display Time at Temperature data against the graphical window. The Datapaq Insight Software includes a facility to perform this task automatically using a digitally created BakeChart (Figure 6). This is obviously far more beneficial than manually plotting data on hard copy bake chart reports. For processes in which multiple coatings or adhesives are cured simultaneously it is possible even to identify the optimal cure characteristics by overlapping the BakeCharts and identifying the common cure region.

*Figure 6 (below):* Insight BakeChart software used to confirm cure for an automotive coating process. Time at Temperature data calculated automatically from the profile is viewed both graphically and in tabular form against the paint supplier BakeChart specification. Correct cure is confirmed easily and efficiently.

Datapaq following extensive collaboration with a key major automotive manufacture and paint suppliers in the USA has further extending the working capability of the BakeChart function. Applying the mathematic relationship of the Datapaq Value which applies the kinetics of Arrhenius cure reaction the BakeChart can be defined or mapped out in terms of the Datapaq Value.

As shown in Figure 7, the BakeChart is used to select the Datapaq Value parameters (three cure schedules on the line marked with Datapaq Value 100). From this reference lines other ISO cure lines can be created to identify a target Datapaq Value and maximum Datapaq Value as defined by the BakeChart. With such data the Datapaq Value “Index of Cure” can then be used, independently of the BakeChart, to accurately quantify the total expected cure from the profile directly against the laboratory paint specification. It makes accurate profiling for any shape or size of product or differing profile shape as easy as checking that the reported Cure Index is within tolerance. Alarms in the same software can be set-up to immediately inform operative when the Datapaq Value is out of specification (Figure 7: DPV < 100 or > 955). Obviously the applicator will strive to attain the target Datapaq Value (341) to give both quality and enhanced productivity so can base any process optimisation on such target.

*Figure 7 (above):* ISO Cure function used to both define Datapaq Value parameters and the acceptable Datapaq Value tolerance range (“Pass / Fail”). For the above example the target Datapaq Value range is min 100, target 341 and maximum 955.