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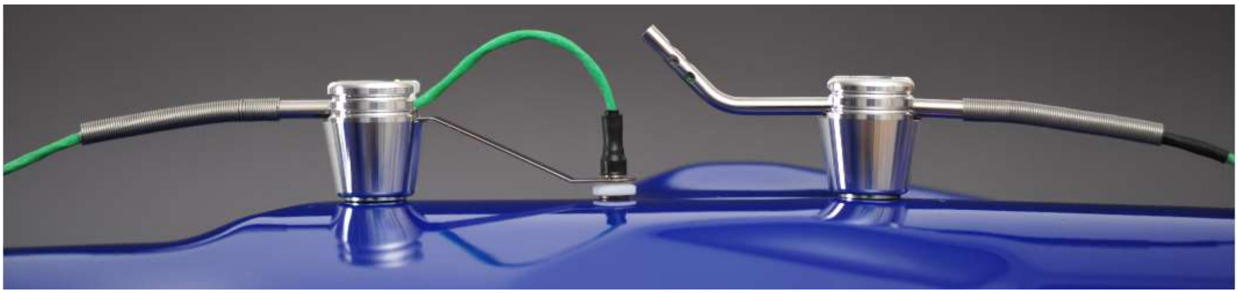
Innovations in Oven Monitoring in the Automotive Coating Industry

...................adding the excitement back into watching paint dry!

Dr Steve Offley - Product Marketing Manager



Introduction – Do you know what truly happens in your automotive paint oven?

Over the last 40 years 'Thru-process' temperature profiling has been established as an important and standard method for proving quality assurance of the paint cure process. Monitoring the temperature of a painted automotive body shell as it passes through the series of sequential cure ovens (Ecoat, Primer, Top Coat & Clear Coat) is critical to prove that the part has been heated correctly in the oven to achieve the desired physical and cosmetic properties of the coating. At the coating stage, significant investment into the product has already been made, so it is even more critical to get the coating process correct, to avoid rework or at worst product scrappage. Getting the cure wrong is a costly mistake to make and the implications from a business perspective are often far more severe than many realise.

The basic concept of thru-process temperature profiling remains very similar to the systems developed in the 1980's, a thermally protected data logger is passed through a cure oven measuring via thermocouples the product temperature throughout its journey to provide a temperature profile. Evolution and automation in the automotive manufacture process, including painting operation, has driven a constant need for innovation in temperature profiling and process monitoring. The following article highlights some of these important innovations.

Safe Monitoring in ATEX classified areas

Over the years regulatory compliance and health and safety has become critical aspect of day to day manufacturing. One important requirement of this in the paint operation has been the need for classification of areas and zones on the paint line against potential explosive risk (e.g. ATEX classification in Europe). A need to identify the explosive risk in key areas and therefore restriction on the type of equipment that can be used in that area brings technical challenges.

Fig 1: PTM1520 Epsilon – x intrinsically safe data logger designed and certified for use in potentially hazardous gas (solvent and wet paint) and dust powder coating environments. Shown with safety standard markings for Europe, USA & Canada where approved.

To perform a temperature profile on a solvent or water-based coating line requires that the profiling system be passed through zones / areas that are classified as potentially hazardous. These areas may include the paint booth, flash off zone and even the paint curing oven itself. In such areas potentially explosive gases / volatile organic compounds (VOC) may be present from solvents such as Acetone, Toluene and Xylene, used in and released from the coatings or as cleaning agents. In a powder coating line, the build-up of dust layers and dust clouds can also create an environmental explosive risk.

Monitoring equipment used in such areas classified as having an explosive risk by regulatory definition needs to be certified to safely operate in that area. This certification varies for both the type of risk i.e. Gas or Dust and also the country or region in which the application and equipment is approved for use.

To address this restriction PhoenixTM has introduced the Epsilon-x a unique intrinsically safe 20 channel profiling system (figure 1). The PTM1520 data logger is certified against the ATEX European standards as Group II category for safe operation in gaseous and dust environments (ATEX Zone 2 and 22 respectively). In the USA the data logger is certified against NEC standards (NEC500&505) as Class I (Gas) and Class II Dust (Division I & II and Zone 2 & 22 respectively). In Canada the data logger is certified against CSA standards (Gas Zone 2 and Dust Zone 22).

Thermocouples to meet changing material requirements

For routine monitoring of the car body shell temperature the default thermocouple type has been the offset magnetic thermocouple (figure 2) allowing quick, easy but accurate and repeatable placement of the measurement sensor on the steel body surface. The PhoenixTM magnetic thermocouples are uniquely designed to allow sensor replacement to keep consumable costs to a minimum. In the paint operation damage to the PTFE cable especially if 3m or more in length is inevitable over time with moving cables across the hostile hot sharp edges of the car body shell.

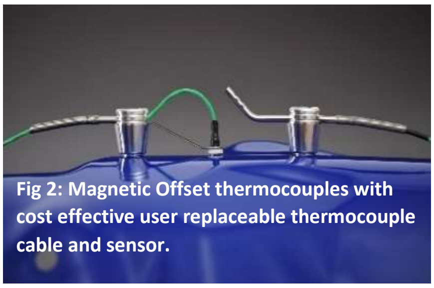


Fig 2: Magnetic Offset thermocouples with cost effective user replaceable thermocouple cable and sensor.

A new addition to the magnetic thermocouple family is the MiniMag thermocouple. With a compact profile the sensor can be mounted in the tightest of recesses. Incorporating the hot junction into the low mass base of the housing, accurate and repeatable contact with the substrate, hence measurement, is guaranteed on attachment. The sensor can be attached to the smallest area of metal (23 mm diameter) so idea for even formed and curved body shells. Provided also with a user replaceable cable consumable cost are minimized as with other PhoenixTM thermocouples developed for finishing applications.

Fig 3: MiniMag - Compact Magnet thermocouple with easy accurate sensor placement

With a drive to reduce CO_2 emissions as part of climate change regulations car body weight reduction strategies has moved materials away from traditional steel to aluminium and composites. If monitoring using a purpose designed non production test body simple exposed junction thermocouples or washer thermocouples (figure 4) can permanently attached using either high temperature tape or screwed into place. If though monitoring a painted production car body such thermocouple fixing methodology is impractical. To address the aluminium challenge a unique long reach clamp thermocouple (figure 5) has been developed. The clamp allows secure fixing on inner structural metal work and a user customized sprung arm allows customized positioning of the measurement sensor on the surface of interest.

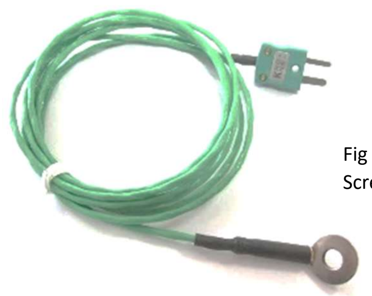
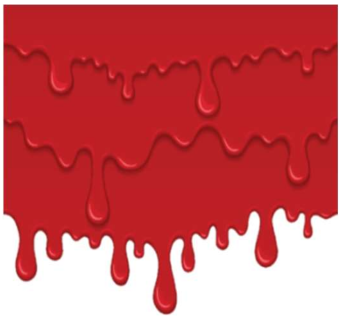


Fig 4: Washer Thermocouple Screwed to test body

Fig 5: Long Reach Clamp Thermocouple Ideal for Al body measurement

Optical Profiling a products eye view!



Thru-process temperature profiling provides a great understanding of what temperatures the product sees travelling through the cure oven. In terms of paint quality though, in particular cosmetic finish and paint defects, this is not the complete story. During the journey through the oven the painted car body can experience many problems that are not temperature related that can affect the quality of the cured paint. Problems such as paint runs, drips, paint or rinse entrapment or condensate contamination can only be detected post process without any specific knowledge of the root cause / location of problem. If only you could see a video of the car body travelling through the oven to allow identification and location of such issues.

The PhoenixTM Optic system (figure 5) has been developed specifically to allow such paint defect detection using Optical Profiling. Adapting the thermal barrier technology used for temperature profiling a high-resolution video camera can safely travel through the paint oven with an independent torch recording video footage of what the product sees. The system is just like your car 'Dash Cam' the only difference being that the journey is through a cure oven operating up to 200 °C. The Optic system can be mounted on a test body allowing monitoring of the exterior of a separate production body shell or potentially directly on a production body itself.

Fig 5: PhoenixTM Optic System used for Optical Profiling of Paint Ovens during full production.

In addition to paint defect detection the Optic system can be helpful in detecting other process problems specifically relating to the oven and conveyor system operation without physically having to access the oven. Identifying oven damage, badly adjusted ducting, faulty fans, failing jerky belt drives can allow pro-active corrective action and prevent lengthy down time and lost productivity.

Live Real Time Paint Line Monitoring

Large OEM automotive paint lines are all closely monitored and controlled by sophisticated monitoring systems. Such systems are generally based on monitoring of control thermocouples within zones of the various ovens. Although giving 24/7 monitoring capability obviously such data does not give actual product temperature. For years process engineers have been striving to achieve continuous live product temperature monitoring through the process.

Radio telemetry as a technology allows in theory direct data transfer from a data logger out of an oven to a monitoring PC providing such live monitoring. Although well known the technology has rarely been applied to temperature profiling in the automotive paint market. The reasons for this are generally down to the distance over which the signal needs to be transmitted (Oven to QA Office), number of receivers needed to detect a signal out of the oven and the costs associated with configuring receiver units hard linked by cable and needing external power to operate. Even with expensive RF configuration any data gaps in the process, due to large ovens, faraday gage effects and transient RF interferences can make comprehensive monitoring difficult and non-conclusive.

To overcome the inherent technical limitations of existing RF system on the market PhoenixTM has developed its own unique RF telemetry system. The system has been designed in such a way as to overcome the inherent challenges of the automotive paint line. The two-way RF system not only monitors temperature data recorded by the data logger but allows direct control of the data logger itself. The data logger can be reset or downloaded direct from the oven without any need to access the data logger inside the thermal barrier. The RF signal transmitted out of the oven is passed along a series of repeater units (figure 7) back to the main coordinator connected to the monitoring PC. The repeater units are powered by battery and are not physically linked by any cable. As such they can be positioned where needed and moved with ease (No expensive infrastructure installation costs). For a paint line it is possible therefore that each oven has its own allocated repeater(s). A very valuable feature of the system is a unique 'catch up feature'. Any missed data from RF black spots is automatically re-transmitted as soon as the RF signal is re-established ensuring that profile data is complete.

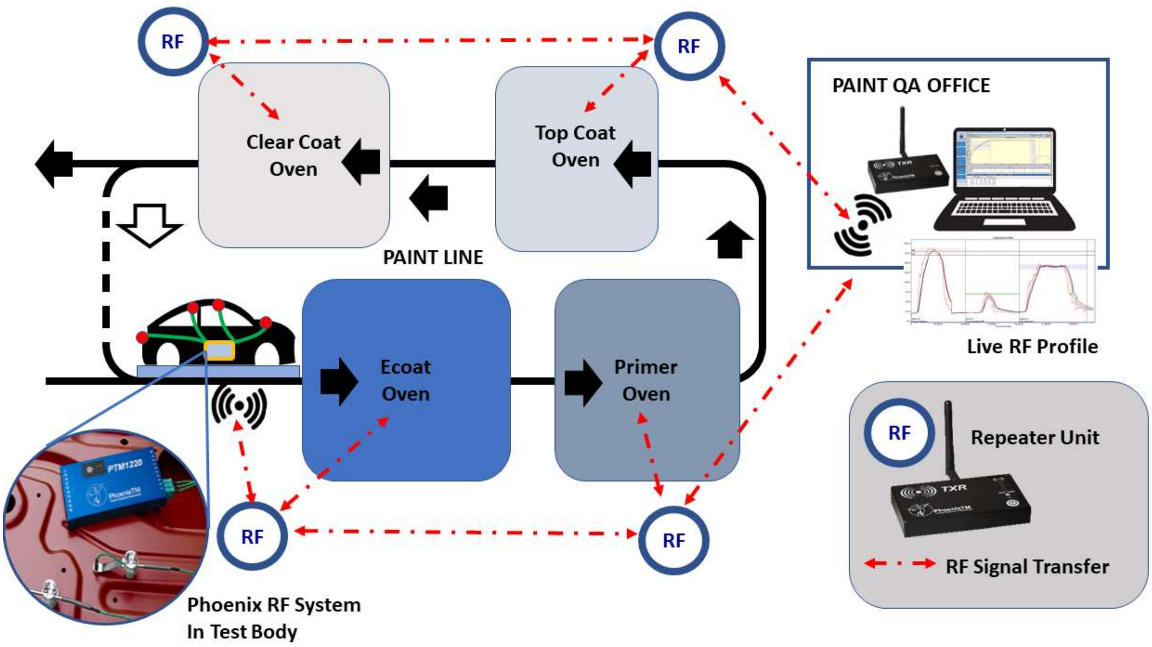
Combining RF telemetry with the performance of the profiling system it is possible to monitor the complete paint process in one continuous run. This approach eliminates a lot of the intensive labour required for traditional manual profiling of each oven. System set-up installation and retrieval for each oven is tedious, time consuming, not forgetting the travel time from oven back to the QA office to download the profile data.

The Thermal barrier (figure 6: TS04-135) provides up to 5 hours protection @ 200 °C. So, with the delays between ovens (cooling period) it has enough thermal protection to allow all coating ovens to be run in one profile pass. With RF operation the data is collected automatically and process issues can be detected immediately. With a battery life of up to 1000 hours and 3.8 M data point memory in theory the system could run continuously in RF mode for a complete manufacturing week (6.5 days).

Fig 6: PhoenixTM TS04-135 Thermal Barrier providing 4.8 hours protection @ 200 °C allowing single pass profiling of entire automotive paint line (Ecoat, Primer, Top coat Clear coat)

Fig 7: PhoenixTM Remote repeater used to transfer RF signal back from Ovens to monitoring PC

It is potentially feasible that a car test body permanently fitted with a RF system and thermocouples permanently fixed in place could run continuously around automated paint cure loop (figure 8) performing a daily profile of all cure ovens without any operator intervention other than programming the insertion of the test body in to the product stream.



After each weekly cycle the data logger could be retrieved to allow battery replacement and weekly data downloaded for archive. If necessary, from the complete profile trace individual oven profiles can be extracted using a profiling splitting feature for more detailed analysis and reporting.

Accurate Cure Analysis – flexible graphical and cure index choices

To quantify the success of the paint cure process from the temperature profile trace focus is given to whether the product achieved the correct time at temperature in direct comparison with the coating suppliers specified cure or bake schedule.

Achieving the correct time at temperature strongly influences the rate of the cure reaction, degree of cross linking and so the properties of the cured coating. If insufficient time or temperature is achieved the coating will be under cured and potentially have compromised physical and cosmetic properties. Over curing although not likely to create major physical coating issues will compromise process productivity, energy efficiency and may be detrimental to coating cosmetic properties such as gloss and colour.

Globally Automotive OEM operations apply different methods for applying cure schedule analysis from, at its simplest, basic Time @ Temperature calculations to graphical cure analysis called Bake/Cure Chart, Cure Window analysis (figure 9) or mathematical Index of Cure analysis.

Fig 8: Schematic of RF system configured for an Automotive paint line allowing real time monitoring of all ovens in a single continuous run.

Applying a single Time @ Temperature or even a Bake window QA approach can be in some situations be misleading and not give the full picture. As cure rate is significantly influenced by temperature it is ideal to include all profile data when trying to quantify cure. Peaks in temperature above the target cure schedule temperature and even temperatures below can contribute to the total cure which are ignored in the basic single time @temperature calculation.

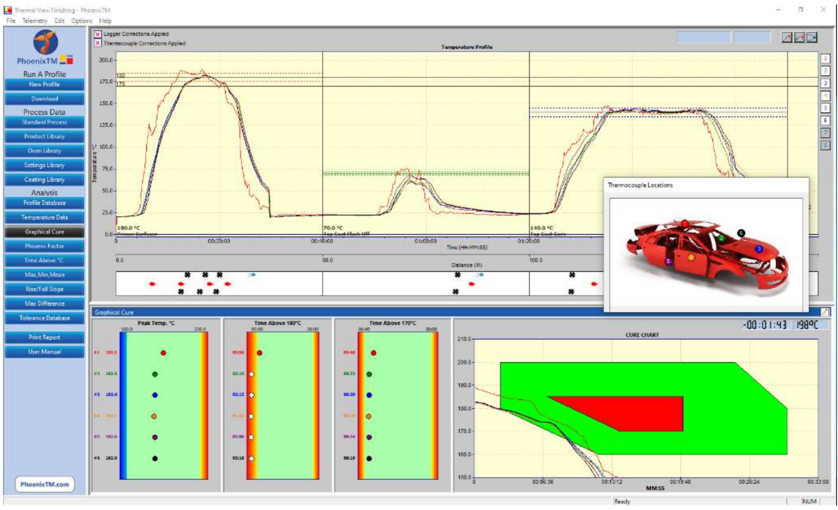


Fig 9: PhoenixTM Thermal View Finishing Software showing the CureChart graphical cure analysis function

To provide an accurate method to quantify cure PhoenixTM have developed its own mathematical index of cure calculation referred to as the Phoenix Factor. A constant cure curve is created from the coating suppliers cure schedule information. Different line fit algorithms can be chosen to create the best line fit to up to 10 cure schedule data points for each individual coating. From this constant cure line (figure 10) any profile data value (Sample interval 5s @ X °C) can be translated into an equivalent time at the target cure schedule. Converting every data point in the profile graph therefore provides a theoretical equivalent total time at the nominal cure temperature.

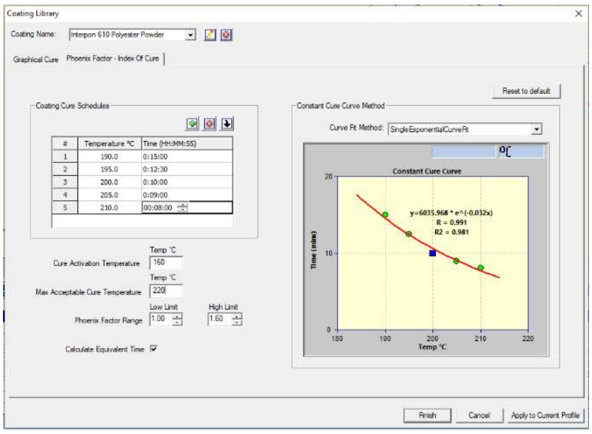


Fig 10: PhoenixTM Thermal View Finishing Software Phoenix Factor – Coating Library file with defined Constant Cure Curve.

If the equivalent time matches the target cure schedule time the resulting Phoenix Factor is 1.00 a situation of theoretical perfect cure. Correspondingly a value of <1.00 denotes under cure and >1.00 over cure. The Phoenix Factor gives an easy instant cure indicator which allows different profile traces to be compared directly whatever shape or form they may have. Monitoring the value over time gives a perfect means to show if a process is changing and may predict future cure problems which can be proactively avoided.

Combining the calculation tool output with independent physical testing allows the paint engineer to define what range of Phoenix Factor values is acceptable for a particular paint system. This range then can be used in the Phoenix Factor Graphical Tool to visualise PASS and FAIL conditions as shown in the Profile Report shown in figure 11.

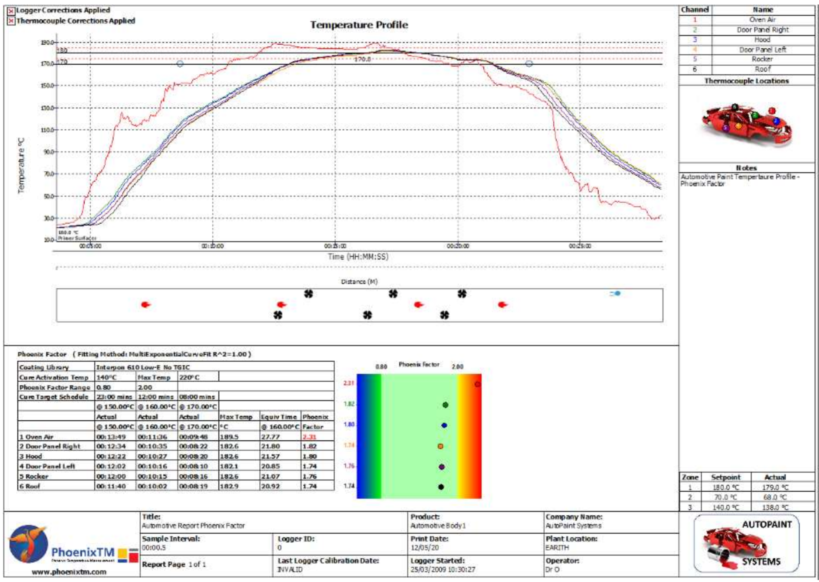


Fig 11: PhoenixTM Thermal View Finishing Software Phoenix Factor – Report and Graphical Pass/Fail Tool.

Phoenix Factor values for all product thermocouples are >0.80 and <2.00 therefore within specification validating cure compliance.

Summary

In the modern automotive paint pant innovation is not only restricted to the development of new coatings or use of new construction materials. As shown in this editorial, major steps have also been made in the process monitoring of the paint cure process itself. The thru-process monitoring technique is now safer, in areas classified with an explosive risk, with the availability of certified intrinsically safe monitoring systems. For the first time operators are able to combine optical and temperature profiling benefits to truly see what happens inside their oven. Innovation in RF technology now permits the concept of semi-automated live monitoring to take the labour our of traditional batch profiling. Data analysis and reporting at the same time has been made significantly more accurate through the implementation of the flexible Phoenix Factor theoretical cure analysis tool. Rediscover the full excitement of watching and monitoring your paint dry!

For more information: Contact Dr Steve Offley - Product Marketing Manager; PhoenixTM Ltd UK; tel: +44(0)1353223100; e-mail: Steve.Offley@phoenixtm.com; Web: www.phoenixtm.com

PhoenixTM LLC USA: info@phoenixtm.com; PhoenixTM Ltd UK ; sales@phoenixtm.com; PhoenixTM GmbH Germany: info@phoenixtm.de