Introduction

Baking Temperature

Today's industrial mass production would not be possible without the use of baked coatings. Drying times (baking times) varying between a few minutes to half an hour are common in the production process.
Today's finishes must meet very high mechanical and appearance QC requirements, including
- Optimum adhesion
- Sufficient elasticity in case of deformation through mechanical stress
- Long-term weather stability, e.g. corrosion resistance
- Gloss and color stability
- Optimum hardness

Optimum curing is the prerequisite for achieving these specifications. The properties and the exact temperature distribution of the oven must be known in order to avoid rejects and ensure consistent quality. Poor curing can lead to failure:
- Insufficient adhesion to the substrate
- Insufficient elasticity to resist mechanical stress
- Insufficient surface hardness
- Premature aging, brittleness and chipping, leading to rust and corrosion
- Discoloration and loss of gloss

Any of these damages can be costly to repair.

The traditional range of baked coating systems has changed considerably with the introduction of environmentally friendly systems. The following types of paint technologies are being used:
- Conventional, solvent borne systems with 50% to 60% organic solvents
- High-solids with 10% to 30% solvents
- Water-borne paint systems
- Powder coatings, 100% solids and 0% solvents

Thermoset coatings (acrylic, polyester, epoxy or alkyd resins) are established finishes for industrial applications.

The right catalysts and amount of heat initiate the cross-linking process among the various components. The result is a compact paint system consisting of polymers, resins, binders and pigments, which is to be chemically resistant and long-lasting.

Paint properties largely depend on cross-linking quality. Today's binders are very sensitive to insufficient cross-linking.

TEMPERATURE

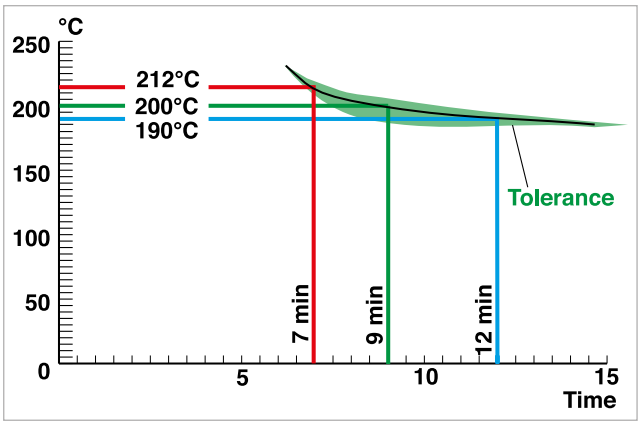
Insufficient cross-linking causes
- Soft films with low hardness
- Poor or no chemical resistance
- Poor weather resistance (UV, SO2, etc.)
- Increased gloss
- Lower haze values

Insufficient cross-linking can also result in
- Better adhesion
- Better flexibility
- Better intercoat adhesion

Over-cross-linking causes
- Increased hardness
- Less flexibility
- Less gloss
- Higher haze values
- Poor adhesion or intercoat adhesion
- Improved solvent resistance
- Yellowing or discoloring
- Less outdoor resistance, especially when subjected to UV radiation

In order to determine the optimal cross-linking parameters of a system, a series of tests must be carried out at different baking temperatures. Minimum and maximum baking temperatures determine the limits of an optimal curing process. In this process, time and temperature can vary. The reaction speed changes with the temperature, but in a non-linear manner. The heat-up speed is another key factor for solvent based and aqueous systems. If the heat-up speed is very high the solvent evaporates too quickly and pinholes may occur causing poor appearance.

The example below shows three different theoretical temperature profiles with identical curing. Slight temperature changes have a big impact on the curing time.
In the production process the temperature profile will rarely be so simple, since material thickness is never constant and oven temperatures vary due to external influences.



Baking Ovens

Baking properties of new paint systems need to be tested and optimized in the laboratory. This is usually done with a convection oven. The coated test panel is put into the preheated oven for a set time. To this point the process in the laboratory is identical with the process in the production line. This stage in development is very time and labor intensive. Many test panels have to be baked at various temperatures and times. This is the only way to accurately determine the optimum temperature and baking time.

In addition, it is difficult to accurately reproduce a constant sample temperature and heat-up speed of the sample using several convection ovens.

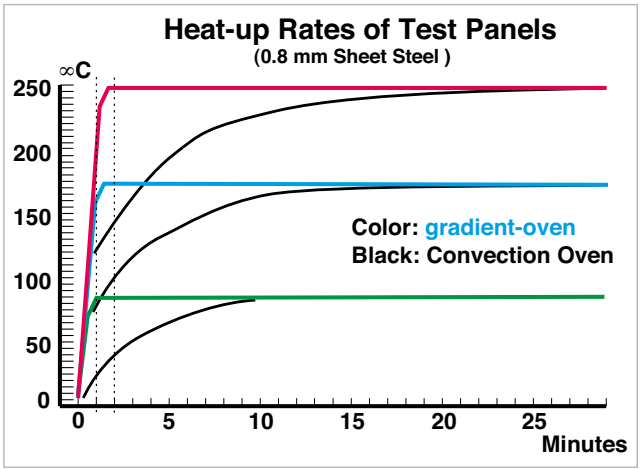
gradient-oven

BYK-Gardner offers a well established type of baking oven – the gradient-oven – for better control, higher precision and production simulation in the laboratory.

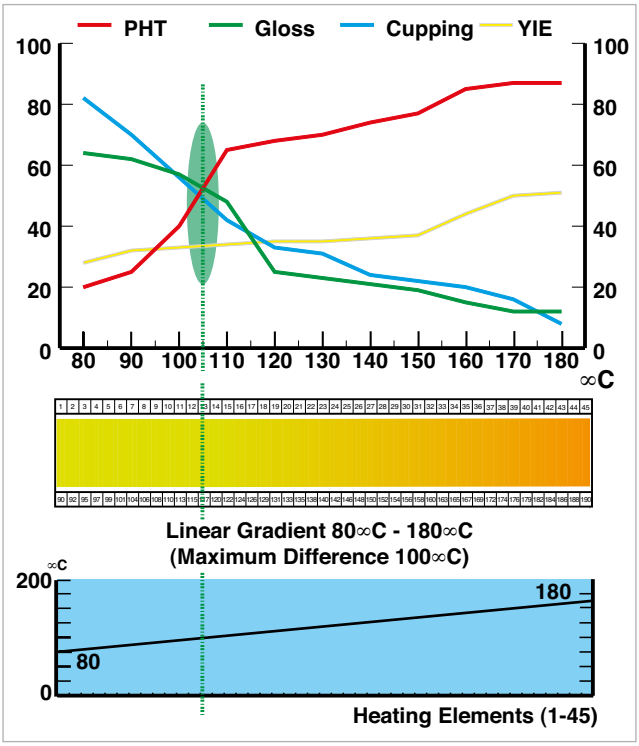
The gradient-oven houses a microprocessor-controlled heating bank consisting of 45 heating elements, each equipped with a Pt-100 temperature probe. Each element is separately insulated allowing the setting of different temperatures at two adjoining elements.

The coated test panel 22 x 4 inches (560 x 100 mm) is automatically transported onto the heating bank with the help of a sample pressure device guaranteeing quick heat transfer. The heating area is enclosed by a special cover situated approximately 2 inches (50 mm) above the test panel.

Comparison of convection ovens with the gradient-oven
Comparison measurements between convection ovens and the gradient-oven show the following temperature profiles.

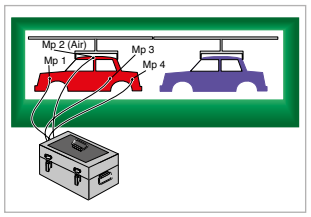


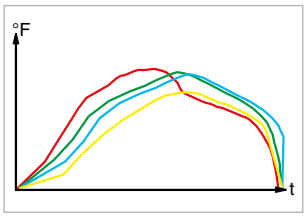
Testing with the gradient-oven provides major benefits:
- QC of color, appearance and physical properties can be performed with continuous temperature variation on one panel
- A panel can be baked with various temperature profiles:
  - constant temperature over the entire test panel
  - linear gradients with a maximum difference of 100 °C
  - step gradients of different temperatures
- Heat-up speed and baking time can be set in such a way that production baking conditions can be simulated in the laboratory
- High accuracy allows reproducible results and avoids repetitive tests
- Major savings on application time, coating material, the number of used test panels, energy and time



Oven Temperature Recorders

In order to gain maximum output of a production line the baking oven must fit perfectly into the process. The method of heating the oven (gas, oil, electricity), and air distribution as well as the assembly line speed are parameters which must be taken into account for the control of the oven. The oven temperature is influenced by power variations and oven construction. The object temperature depends on parameters such as material, material thickness, the place of suspension (top, middle, bottom), and assembly line speed. It is essential to check whether an oven works properly to ensure right heat-up of an object, guaranteeing optimal cross-linking and curing.Geometrical shape, size and material type also play a major role in the heating characteristics of the object. In order to guarantee a consistent temperature at a set baking time it is necessary to directly measure the object temperature – this is especially true for complex-shaped objects with varying thickness.
The internal temperature distribution of an oven needs to be controlled at regular intervals. Quality assurance according to DIN ISO 9000 also requires professional documentation and increased accuracy. BYK-Gardner's oven temperature recorders fulfill these requirements.





temp-gard

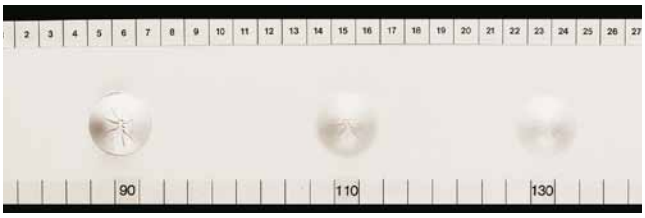
A significant improvement in the recording of oven processes has been made with the temp-gard.
This measurement system stores the analog signals of temperature probes in digital form. A measurement module accompanies the object on its way through the oven without needing a trailing cable. The recording module is protected by a thermal barrier made of stainless steel with absolutely temperature safe insulation.

The digital data is transferred to a computer for further processing. Each measurement is saved as a file.

The temp-gard system controls the curing process and immediately evaluates the results. Within a few minutes all important information is available on the screen and can be printed out:

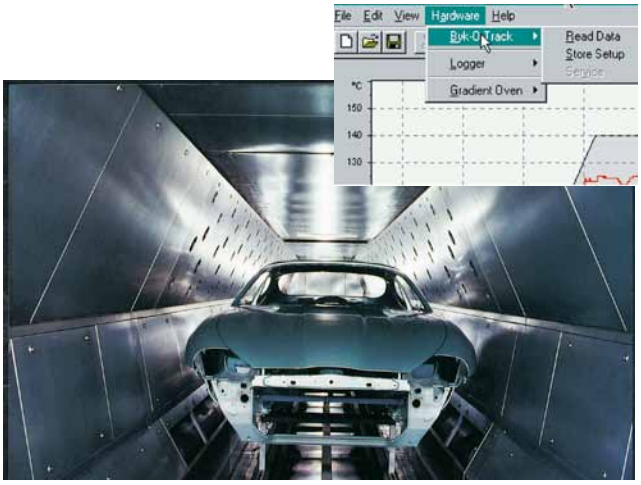
- The measurement points of the object
- Date and time of the measurement
- Name of the operator and identification of the oven
- Temperatures in °F or °C
- 4-color graphic of the entire measurement curve with display of temperature and time

The peak temperature and a warning message occur when the maximum temperature of a probe is above the control value. It is possible to quickly and regularly check and document the quality of daily production. In addition, this temperature measurement system allows control of oven performance without risking loss of quality.



test panel is cured in the gradient-oven using the temperature profile of the production oven

BYK-Gardner offers a complete solution for testing all important color, appearance and physical properties on one gradient-oven panel.



temp-gard collects temperature data in production oven.

temp-gard temperature data is transferred to gradient-oven.

Production Conditions in the Lab

The methods of storing oven temperature curves as described above can also be used for simulation in the laboratory. The transfer of a temperature profile measured on a certain object to the gradient-oven allows the complete simulation of industrial baking processes in the lab. All 45 heating elements of the gradient-oven heat up the coated test panel in the laboratory according to the temperature profile of the industrial oven in the production line. The accuracy can be checked via comparison of set and actual temperature on the screen. With this method the paint manufacturer can measure the temperatures of his clients' ovens, archive the data and simulate the curves with the gradient-oven when needed.

cupping tester

pendulum hardness

micro-gloss

spectro-guide