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Technical Information

IS04

Performance Colors & Glass

Process Temperature Control Rings (PTCR)

Higher quality products and lower costs through improved, reliable firing control

Take control of your firing process

In the manufacture of ceramic products, the accurate control of the firing process is of highest importance. After all the results have a direct effect on the quality and the costs of the final product.

Optimal firing control requires both, accurate measurement of the quantity of heat - e.g. by measuring the temperature over time of a test specimen with constant mass and physical properties - and the ability to control the temperature and its uniform distribution throughout the kiln. Efficient process temperature measurement is a key to high product quality.

By approximation the temperature can be measured at different places in the kiln. However most conventional temperature measurement techniques are limited in their applicability.

For example, the thermocouples often used in the ceramic industry do not measure the temperature of the product itself but that of its vicinity. They are also limited to measuring radiated heat and take no account of heat transferred from kiln furniture.

A much better measure for the actual absorbed quantity of heat is the shrinkage of a ceramic ring made out of defined material and optimized for the desired application.

Process Temperature Control Rings (PTCR): How It Works

Process temperature control rings are highly accurate ceramic indicators for the actual quantity of heat that has been absorbed during the firing cycle.

PTC rings take account of the radiated heat in the kiln as well as the transferred heat through the kiln lining etc., during the whole firing cycle.

The quantity of heat Q that is transferred to the ring is directly proportional to the firing temperature ΔT and firing time t [1]:

$$Q \sim \Delta T * t$$

The sintering process causes the ring to contract. It continues contracting as long as the peak temperature is maintained. This shrinkage is also proportional to the sintering temperature and sintering time [2]:

$$\frac{\Delta L}{L_0} \sim F(T) * t$$

with ΔL= change of the diameter during the sintering process, L_0= diameter before firing, t= firing cycle time. The function F(T) comprises the absolute temperature as well as material specific and geometric factors. The degree of contraction is almost linear over the complete operating range of the ring.

Combining the two formulas results in a proportionality of ring contraction and total absorbed quantity of heat:

$$\frac{\Delta L}{L_0} \sim Q$$

The amount of contraction - the amount by which the ring diameter has shrunk - is measured with a micrometer.

For ease and for comparison this shrinkage - and therefore the total absorbed heat quantity - is translated into a single, fictitious conversion parameter, the so-called „ring temperature“ (RT). Basically, this is not a „temperature“ but a parameter that depends on time and temperature. The RT for example does not reflect the maximum temperature of the firing process and does not correspond to the real kiln temperature because the PTCR accumulates the absorbed heat quantity over time.

Converting to Ring Temperature

The measured ring diameter is converted to ring temperature using the conversion table enclosed in each packing unit. Each table is specific to the particular batch of rings for each ring type.

The ring temperature is a practical single number which is useful for comparison purposes, for instance to relate the recorded quantity of heat to standards, so that any required adjustments can be made.

In order to compare the different firing cycles, a standard has to be defined. This is done by including PTC rings in a series of firings and relating their ring temperatures to the quality of the products produced.

The ring temperature which corresponds to products fired to the correct specification can be used as the standard.

Application and Advantages

Originally PTCR has been developed for critical firing processes for electronic ceramic components. Nowadays, the benefits of easy, accurate measurement are used in a wide range of industries.

PTC rings can be used in both batch and continuous tunnel kilns. They are suitable for different kiln atmospheres. In case of vacuum, reductive atmosphere or nitrogen, please contact our technical service staff.

There are seven different ring types, each in 3,5 mm (named L) and 7 mm thickness (named H) with an outer diameter of 20 mm and an inner diameter of 10 mm. They cover a temperature range from 560 to 1750 °C. The ring types are color coded, with batch number and type embossed.

The multifunctional PTCR concept comprises
- ceramic PTC rings in convenient packaging
- the PTCR micrometer with USB-port
- a batch-specific conversion table.

Application

Positioning

PTC rings can be placed at almost any location in the kiln, on kiln furniture, trolleys and the like. The use of multi-location and multi-level positioning is recommended, as this provides the most insight into the temperature distribution within the kiln.

Measurement

The contraction of the ring reflects the absorbed quantity of heat at the point where the ring was located in the kiln. The diameter is easily measured using a micrometer. Only a single measurement is required (see picture).

Correct positioning of the ring in the micrometer is required for accurate measurement.

The “T”´s impressed in the ring should be placed exactly on the indentation of the micrometer.

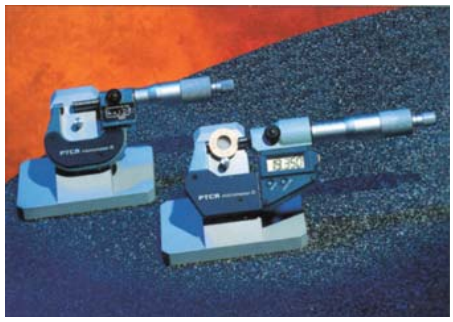
The micrometer with USB-port has an ergonomically designed solid base with a ring positioning chuck, which ensures the ring is always positioned correctly in the micrometer. This design simplifies the measuring process and improves the reproducibility of the measurement.

Table 1: Available range of Process Temperature Control Rings (PTCR)

Temperature range	Product name	Selection of industries applying the PTCR
560 – 660°C	PTCR-ZTH	Decoration of glass and porcelain, annealing furnaces, ULTCCs, semiconductors
	PTCR-ZTL	
660 – 900°C	PTCR-UTH	Decoration of glass and porcelain, sealing glass, LTCC
	PTCR-UTL	
850 - 1100 °C	PTCR-ETH	LTCC co-firing, building bricks and roofing tiles
	PTCR-ETL	
970 - 1250 °C	PTCR-LTH	Pre-sintering ceramics and powders, earthenware, building bricks and roofing tiles, low temperature refractories and kiln furniture
	PTCR-LTL	
1130 - 1400 °C	PTCR-STH	Single and multi-layer capacitors, ferrites and insulators, powder injection moulding, sanitary-ware, table ware and tiles, grinding wheels, medium temperature refractories and kiln furniture
	PTCR-STL	
1340 - 1520 °C	PTCR-MTH	Ferrites, substrates and insulators, tiles and hard porcelain, engineering ceramics, medium - high temperature refractories and kiln furniture
	PTCR-MTL	
1450 - 1750 °C	PTCR-HTH	Advanced ceramics, engineering ceramics, high temperature refractories and kiln furniture
	PTCR-HTL	
PTC ring dimensions: outer diameter 20 mm; inner diameter 10 mm; height 7.0 mm (product name ends with ‘H’) or 3.5 mm (product name ends with ‘L’)		

Table 2: Available range of PTCR micrometers

Product no.	Micrometer type
6387986	Micrometer with USB-port

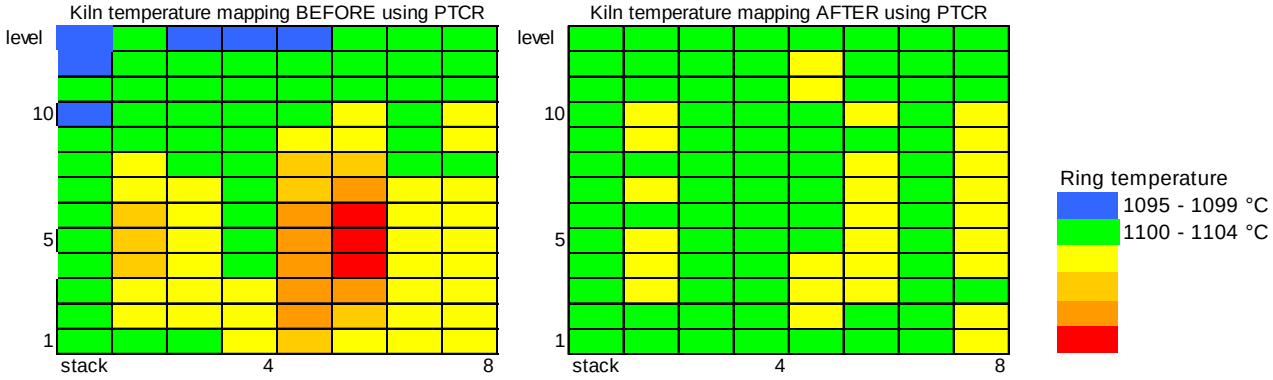


Firing Process Optimization

To determine the heat distribution in the kiln and detect hot and cold spots, the ring temperatures of PTC rings distributed throughout the kiln in a first firing cycle are measured.

The firing process can then be optimized as indicated by the variations in ring temperatures. As a rule of thumb one degree of ring temperature corresponds to one degree Celsius. The exact relationship between ring temperature and real temperature is of course depending upon the specific firing cycle of the kiln.

The adjoining illustration shows two heat treatment mappings of the same 15m^3 kiln. The first was generated before using the PTCR, the second after firing process optimization using PTC rings, resulting in a substantial improvement.



Firing Process Control

In the course of time, hot and cold spots may gradually return to the kiln, caused by aging of the heating elements or frequently alternating firing cycles or the like.

PTC rings can help to monitor the firing process regularly and to detect these deviations early before they affect the product quality.

By comparing the current ring temperatures against the defined standard, the necessity for increasing or decreasing the firing temperature can be determined.

From a statistical viewpoint it is useful to place several rings at critical places in the kiln.

Quality Control at Lower Cost

Besides the benefits of better quality through an optimized firing process, the PTCR can also help to reduce production costs. Simple comparison of ring temperature against a quality standard indicates whether the products are sintered to specification. Expensive, time-consuming quality checks, destruction testing, geometry, density or porosity tests can be reduced or eliminated.

PTCR: Reliable Quality

PTCR is characterized by its accuracy and reliability. The maximum variation is only 3 °RT.
This reliability is based on a stringent manufacturing process. PTC rings are made from a mix of high-grade raw materials. Their composition is fine-tuned through advanced Design Of Experiments- (DOE) techniques, and the production process itself is controlled by Statistical Process Control. Our production is certified according to ISO 9001:2008.

Ferro places great emphasis on the quality of the PTC rings - after all, the quality of the rings has a direct impact on the quality of your products.

All raw materials undergo extensive laboratory testing prior to use. The powders are homogenized and each individual batch is numbered and inspected once more to ensure both physical and pressing properties. A unique batch identifier is pressed into each individual ring, allowing any ring to be traced back to its original powder batch.

Ferro´s unique approach relieves PTCR users of the need to recalibrate or recalculate standards when introducing rings from a new batch. Absolute accuracy is always assured because each individual ring can be relied on to perform as specified in the conversion table.

The PTCR´s accuracy and convenience free you from the concerns of firing quality and control, allowing you to fully concentrate on your product, not on temperature control.

In case of technical questions related to our products and their application, please do not hesitate to contact us.

Literature
[1] H. Stroppe, Physik, C. Hanser Verlag München, 8. Ed. (1990).
[2] F. Thümmler and W. Thomma, The Sintering Process, Metallurg. Reviews, 12 (1967), 115, 69-108.