

## IMPROVED OPERATING CONDITIONS AT FIRING OF ELECTROPORCELAIN INSULATORS IN A TUNNEL KILN

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### ABSTRACT

The firing process of electroporcelain insulators has been studied in a tunnel kiln with working characteristics as follows: 1. Energy source: natural gas,  $Q=34993 \text{ kJ.m}^{-3}$ ; 2. Maximum fire temperature:  $t_{\text{max}}=1320^{\circ}\text{C}$ ; 3. Working length:  $l=43,5 \text{ m}$  (29 working positions); 4. Transport devices: kiln wagons by uniform motion, velocity  $V = 1,09 \text{ m.h}^{-1}$ ; 5. Fire – process duration:  $\tau=40 \text{ h}$ .

As a result of the observations the typical defects which appear during the firing of the products have been specified: 1. Local (under surface) blistering; 2. Darkening of the white colour; 3. Yellow – brown to red colouration on the product surface.

The main reasons for these defects have been cleared up. Recommendations have been given for modification of the technological operating conditions of the kiln. New temperature curve for a defectless firing of the production has been advanced.

Keywords: electroporcelain, insulator, kiln, firing.

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### INTRODUCTION

Electroporcelain insulation products carry out responsible functions in the electrical systems. High requirements for their quality have to be satisfied. This is the main reason why all technological stages of their production have to be realized with the necessary precision.

The burning regime depends on several physical, physico-chemical and chemical transformations, occurring in the electroporcelain body as the result of temperature changes [1, 2]. The burning regime includes the processes of heating and cooling of the production. The incorrect carrying out of these processes reduces the quality of the insulators, can cause failure or electric breakdown and serious accidents can arise. Hence the instructions for the thermal and gas regimes have to be always strictly followed during the burning process.

### OBJECT OF INVESTIGATION

The object of this investigation is a tunnel kiln for burning of electroporcelain insulators in the company ELPROM ELIN – Kubrat, with working characteristics as follows:

- Energy source: natural gas,  $Q = 34993 \text{ kJ.m}^{-3}$ ;
- Maximum fire temperature:  $t_{\text{max}} = 1320^{\circ}\text{C}$ ;
- Working length:  $l = 43.5 \text{ m}$ ;
- Working positions: 29;
- Fire process duration:  $\tau = 40 \text{ h.}$ ;
- Velocity of the material flow:  $V = 1.09 \text{ m.h}^{-1}$ .

The production is loaded on the kiln wagons, which pass through the kiln continuously.

The heating and burning regimes are carried out by 4 separated and independently operated combustion zones in the direction of the material flow mo-

Table 1. Thermal regime according to the used temperature curve.

Parameters	Dimen- sion	Heating regime in the zone					Cooling regime in the zone			
		20-800 <sup>0</sup> C	800-1000 <sup>0</sup> C	1000-1200 <sup>0</sup> C	1200-1320 <sup>0</sup> C	1320 <sup>0</sup> C	1320-1000 <sup>0</sup> C	1000-700 <sup>0</sup> C	700-450 <sup>0</sup> C	450-50 <sup>0</sup> C
Length of the zone	m	13.0	3.4	3.4	2.6	3.7	4.7	4.0	3.5	5.2
Part of the whole length of the kiln	%	29.9	7.8	7.8	6.0	8.5	10.8	9.2	8.0	12.0
Positions in the zone	-	8.3	2.3	2.3	1.7	2.5	3.1	2.7	2.3	3.8
Time of the sojourn in the zone	h	12.0	3.1	3.1	2.4	3.4	4.3	3.7	3.2	4.8
Rate of the heating/cooling	K.h <sup>-1</sup>	65.0	64.5	64.5	50.0	hold time	74.4	81.1	78.1	83.3
Gas medium in the zone	-	oxidizing	oxidizing	reducing	no information	no inform.	no information	-	-	-

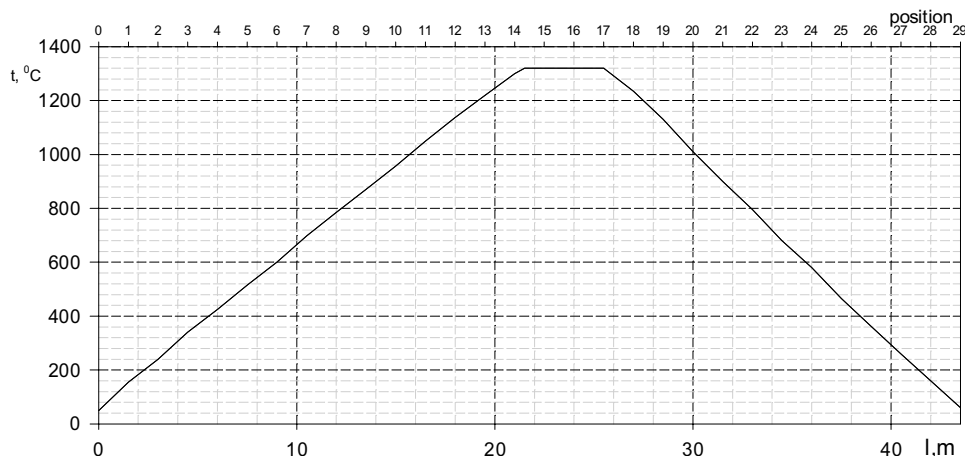


Fig. 1. Presently used temperature curve.

tion. This ensures the necessary servicing in the working area of the thermal regime as well as the gas regime. In the first two zones unheated air is passed for the combustion process. In the following two zones the combustion is sustained by preheating air from the recuperative cooling.

The cooling regime of the production after its burning is realized indirectly with air, which passes through metal recuperators. The sealing at the entry of the tunnel kiln is realized by gas screen, at the exit by air screen.

The thermal regime is carried out according to the temperature curve represented on Fig. 1. So, along the length of the kiln, typical technological zones with parameters presented in the Table 1 can be identified.

## DEFECTS IN THE PRODUCTION AND REASONS FOR THEM

As a result of the observations the typical defects which appear during the firing of the products have been specified:

- Local (under surface) blistering;
- Darkening of the white colour;
- Yellow – brown to red colouration on the product surface.

The analysis of the physical, physico-chemical and chemical properties of the electroporcelain bodies substantiates the following probable reasons for the defects:

- Irregular heating regime in the temperature interval 800-1000°C: High level of body carbonization because of incomplete combustion of the organic mix-

ture and carbon from the combustion products. Carbon does not burn completely and remains in the body before the following reduction zone. The main reasons for this are: a short zone, a scant time for the completed oxidation, a low coefficient of air excess  $\alpha$  of the gas atmosphere in this zone.

- Faulty heating regime in the temperature interval 1000-1200°C: Insufficient time for chemical decomposition of the mixture components, availability of gas phase residue in the body, appearance of melt, compacted and reduced gas permeability of the body. The main reasons are a short zone and low CO concentration in the combustion products.

- Faulty cooling regime in the temperature interval 1320-1000°C: A possibility for oxidation of FeO to Fe<sub>2</sub>O<sub>3</sub>, partial crystallization and opacification of glaze, low degree of whiteness. The reasons for this are the long zone, low rate of temperature reduction and slow cooling of products.

#### ANALYSIS OF THE USED TEMPERATURE CURVE

In contrast to the cited in the literature [1-4,6] optimal temperature curves for electroporcelain insulators in the case studied some essential deviations are observed:

- Zone 20-800°C

The realized heating rate 65 K.h<sup>-1</sup> is too low and hence this temperature zone is unnecessary extended. At the recommended heating rate 80-100 K.h<sup>-1</sup> especially in the temperature interval 400-800°C, this zone could be shortened.

- Zone 800-1000°C

It is respectively short. So, there is no sufficient time for complete combustion of the organic mixture in the mass and of the carbon in the combustion products; for insulators with minimal dimensions  $d = 23-30$  mm insulators, the remain time in this zone have to be 4 - 6 h at the air ratio  $\alpha = 1,3-1,5$  or 2-4 h at  $\alpha = 1,5-1,7$ .

- Zone 1000-1200°C

This zone is short and a high heating rate of 67.5 K.h<sup>-1</sup> is realized. At present the content of the gas medium is not controlled. An obligatory condition is to maintain reduction atmosphere through incomplete fuel combustion ( $\alpha = 0.93-0.95$ ) and a content of 2-4 % CO in the combustion gases. In the interval 1150-1180°C formation of a melt with high viscosity starts. Hence, all preliminary processes in the body have to be realized before that.

- Zone 1200-1320°C

In the present condition this zone corresponds to the requirements, but it could be shortened with 2-3 % (~ 1 position) without reflection on the burning regime.

- Zone 1320-1000°C

Unreasonably long zone with a low cooling rate of 74.4 K.h<sup>-1</sup> awhile the allowed values are 170-250 K.h<sup>-1</sup>. This zone could be realized only by two working positions. Here, the defects in the production caused from the breakdowns in the temperature regime in the second and in the third zone are seen.

- Zone 1000-700°C

The zone has a suitable length and cooling rate of 81.1 K.h<sup>-1</sup>, which is close to the optimal one.

- Zone 700-450°C

The zone is short and temperature loaded because of a high cooling rate of 78.1 K.h<sup>-1</sup>. At the allowable rate of 40-50 K.h<sup>-1</sup> the length has to be increased with 5-8 % (1.5 - 2 positions).

- Zone 450-50°C

An appropriate temperature regime is realized in the zone.

#### CONDITIONS FOR IMPROVING THE WORKING REGIME OF THE KILN

On the basis of the observed defects in the production, the reasons for them and the analysis of the thermal regime the following is necessary to be done for its improving:

1. Shortening of the first zone to approximately 6 positions (21-23 % from the kiln length) and increasing of the heating rate up to 80 K.h<sup>-1</sup>.
2. Extension of the second zone (800-1000°C) to approximately 3.5 positions (11-12 %).
3. Extension of the third zone (1000-1200°C) to approximately 3.5 positions, keeping of a reduction gas medium (CO = 2-3 % at  $\alpha = 0.93-0.95$ ).
4. Keeping of low reduction gas medium (CO = 1 % at  $\alpha = 0.97-0.98$ ) in the fifth zone with maximum temperature 1320°C.
5. Shortening of the sixth zone (1320-1000°C) to ~ 1.5 positions (4-5 %), creating conditions for fast cooling of the production at rate: 120-140 K.h<sup>-1</sup>.
6. In the seventh zone (1000-700°C) – keeping of neutral medium conditions.
7. Extension of the eighth zone (700-450°C) to ~ 6 positions (18 %), reduction of the cooling rate to 40-50 K.h<sup>-1</sup>.

Table 2. Thermal regime according to the proposed temperature curve.

Parameters	Dimension	Heating regime in the zone				Cooling regime in the zone			
		20-800 <sup>0</sup> C	800-1000 <sup>0</sup> C	1000-1200 <sup>0</sup> C	1200-1320 <sup>0</sup> C	1320-1000 <sup>0</sup> C	1000-700 <sup>0</sup> C	700-450 <sup>0</sup> C	450-50 <sup>0</sup> C
Length of the zone	m	9.0	5.2	5.2	4.0	2.6	3.8	7.8	5.8
Part of the whole length of the kiln	%	20.7	12.0	12.0	9.3	6.0	8.7	18.0	13.3
Positions in the zone	-	6.0	3.5	3.5	2.7	1.7	2.5	5.2	3.9
Time of the sojourn in the zone	h	8.3	4.8	4.8	3.7	2.4	3.5	7.2	5.3
Rate of the heating / cooling	K/h	94.0	41.7	41.7	32.4	133.3	85.7	34.7	75.5
Gas medium in the zone	-	oxidizing $\alpha = 2.0$	oxidizing $\alpha = 1.6$	reducing $\alpha = 0.92-0.95$	slight reducing $\alpha = 0.98$	neutral	-	-	-

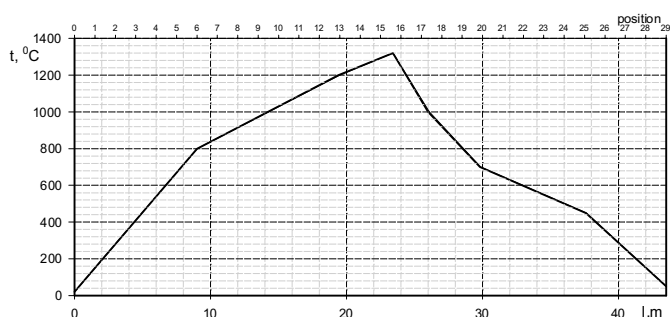


Fig. 2. Proposed new temperature curve.

### A NEW TEMPERATURE CURVE

On the basis of the conditions for improving of the technological regime of the kiln [4-7], the new temperature curve, presented on the Fig. 2 is proposed. According to this curve, the processing of the production will be realized by a thermal regime with parameter values, shown in the Table 2.

### CONCLUSIONS

According to the proposed new temperature curve for achieving of the desired operation effectiveness it is necessary:

- Restoration and modernization of the system for control and regulation of the temperature and the air - to fuel ratio in the separated zones.
- Strict keeping of the gas medium composition (oxidation, reduction) in accordance with the temperature zones.
- Strict keeping of the level of filling and the granular composition of the sand gasket canals of the kiln.
- Observation of the conditions for uniform loading of the wagons with production. If there are signifi-

cant differences in the loading, possibilities for organization of the material flow through the kiln in the so called "heavy" and "light" echelons have to be investigated.

- For the reorganization of the material flow in "heavy" and "light" echelons the respective calculations of the thermal regime of the kiln have to be made.

The execution of the indicated recommendations ensures a success for high quality of good. Simultaneously it gives certain preconditions for reduction of the energy consumption and production cost.

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