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ENERGY CONSERVATION THROUGH INCREASED EMISSIVITY IN FURNACES

I. BENKŐ

Institute of Thermal Energy and Systems Engineering
Technical University, H-1521 Budapest

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Abstract

The article describes a new method which increases radiation heat transfer of furnace refractory linings. The method, which is the application of a high emissivity coating, results partly in energy savings, partly increases gas tightness and life span of the lining. As heating time is decreased, the method also makes the operation of the furnace more flexible. Application of ENECOAT furnace coating increases the emissivity of ceramic fibre insulations by 45 %, while that of shamotte by 20 %. The phenomenon is illustrated by infrared thermograms. Industrial applications are also referred to.

Keywords: refractory materials, furnace, energy saving, high emissivity coating.

Introduction

In the past years great attention has been paid to studying the emissivity of kiln linings and to energy conservation through utilisation of high emissivity coatings, the latter well complementing the use of low density insulating materials, such as ceramics fibres and refractory bricks [1, 2, 3].

The factors affecting the infrared radiation of furnace surfaces and high temperature industrial equipment have not yet been studied widely enough.

The efficiency by which materials radiate is defined as emissivity [4]. Its value depends on the surface temperature and material properties of the radiating object, and on the radiation wavelength. It has been shown that the emissivity of refractories drops as the temperature increases. For instance, if the emissivity of a given type of a shamotte refractory brick is 0.9 at a temperature of 130 °C, at 1030 °C the emissivity might well be 0.5 (*Fig. 1* and *Table 1*). Recent research has been focused on high emissivity coatings of ceramic fibres, which increase the fibres' mechanical strength and the emitted energy. Experiments revealed that by employing a silicon-carbide based coating the emissivity of a ceramic fibre can be increased to 0.56–0.63 from 0.498.

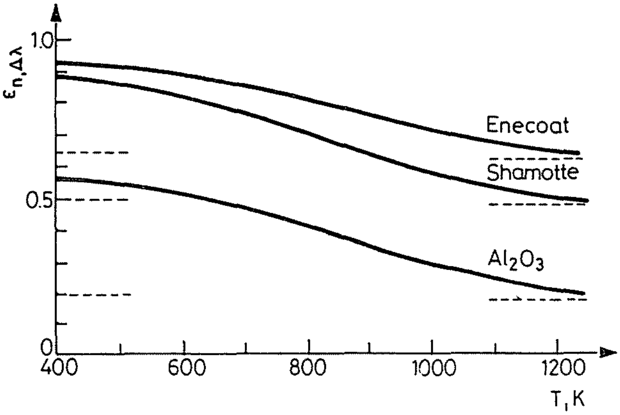

Fig. 1. Spectral normal emissivity of Enecoat, shamotte and ceramic fibre (Al_2O3) against material surface temperature

Table 1
Total normal emissivity of different ceramic materials

Brick material	t[°C]	ε_n
shamotte	20	0.85
shamotte	1000	0.75
shamotte	1200	0.59
corundum	1000	0.46
magnesite	1000 to 1300	0.38

Ceramic fibre insulating materials (such as Al_2O_3) have poor heat radiation properties (*Fig. 2*) but their insulating property is good at operating temperatures up to 1200–1400 °C. However, ceramic fibres have much lower mechanical strength than traditional fireclay based materials. A recently opened way of dealing with these drawbacks is the application of suitable coating materials. Their purpose is on the one hand to improve the strength and surface properties of the ceramic fibre, and on the other hand to increase the infrared emissivity of the surface.

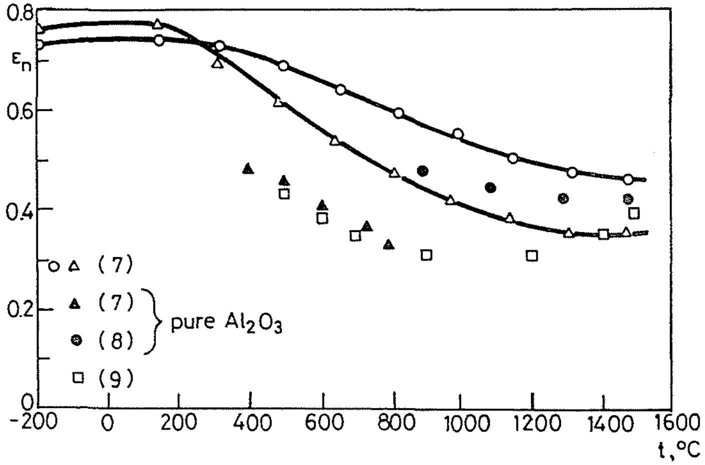

Fig. 2. Total normal emissivity of different Al_2O_3 materials

Objectives of the Hungarian Research

Research within the framework of the Hungarian Research Project OKKFT G/4–V.7 was based on a silicon carbide based furnace coating, Enecoat[1] (in Hungary available under the name Thermodam[2]). It is applied by spraying the material to a thickness of up to 1 mm. The coating after being allowed to dry for 24 hours and then being subjected to an annealing process, forms a hard uniform layer, binding both mechanically and chemically very well with the refractory material beneath. Its emissivity is considerably greater than that of the material onto which it has been applied.

Application is also possible in furnaces already in use during the maintenance shut down periods. Experience shows that the coating slows down detrimental changes which occur in the chemical structure of the insulating materials, hence also erosion and wear.

As neither infrared radiation nor its effects are well understood, applied research has been carried out using a variety of refractory materials and bricks (dense and lightweight refractory block, castable refractory concrete) which are used in Hungary, as well as different types of foreign ceramic fibre (*Fig. 1*).

This paper gives an account only of the Enecoat effects in improving infrared emissivity.

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[1] Enecoat R/MPK Insulation Ltd. Colchester, Essex CO2 8JU, England

[2] Thermodam R/Multitrend Kft., H–1027 Budapest, Varsányi Irén u. 13., Hungary

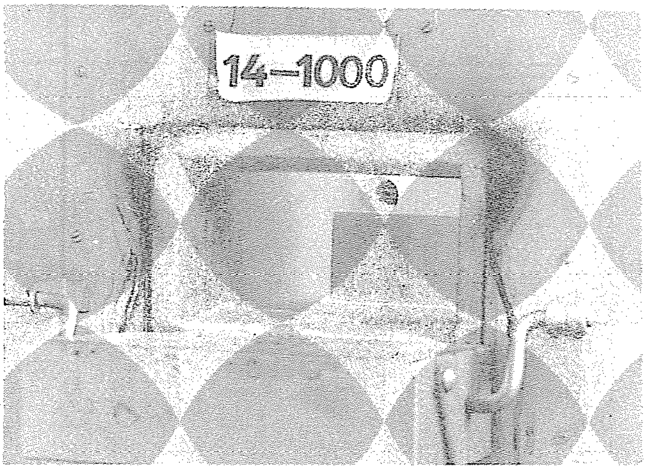

Fig. 3. One of the samples in the furnace for examination of the Enecoat effects

Test Methods

The infrared radiation of samples made of different insulating materials was examined in electric furnaces (*Fig. 3*) at temperatures ranging from 100 °C to 1000 °C (measured by a thermocouple). One half of each sample was coated with Enecoat (E) and the other half (R) was left uncoated (*Fig. 4*).

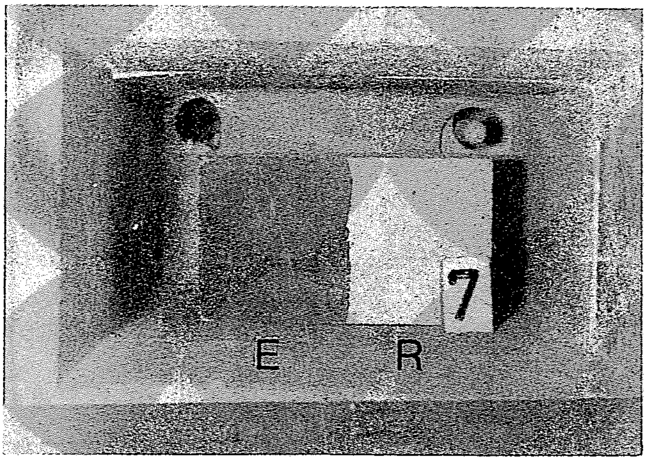

Fig. 4. Detrick 1500H ceramic fibre (see R part), left part coated with Enecoat (see E part)

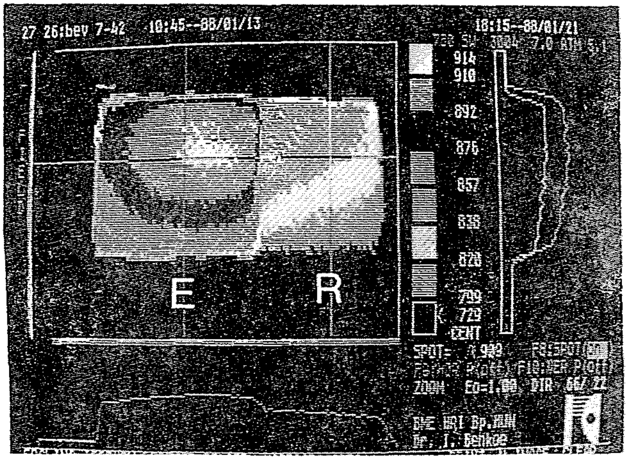

Fig. 5. The two temperature curves on the right show that Enecoat directly increases the infrared emissivity of the Detrick material

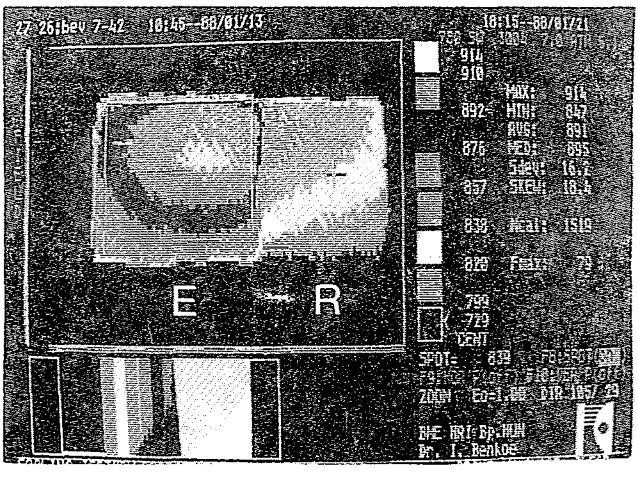

Fig. 6. Thermal image showing an uneven heat radiation distribution and a greater infrared emissivity of the Enecoat (historical representation of the infrared thermograms)

Infrared radiation was measured by the AGA THV 780 thermal imaging equipment. This was done by heating the sample in the furnace to a desired temperature, then placing a shield (surface temperature 20–40 °C) over it to screen it from the furnace so that the radiation of the sample could be accurately measured. The process took a few seconds and the video recording of the infrared measurements was subsequently evaluated by means of computer analysis (*Figs. 5* and *6*).

These images revealed a greater infrared emissivity of the Enecoat on the samples (left side), and uneven temperature distribution as a function of inner furnace height, as well as the effect of thermal conduction in a few samples.

Given these results, a method was worked out for evaluating temperature distribution on the surface of the samples and for calculating the emissivity at given temperatures. The average temperature values of the different surfaces (coated and uncoated) were compared and the temperature distribution in various vertical and horizontal cross-sections of the surface was analysed.

Figs. 5 and *6* illustrate the infrared thermal images obtained as a result.

Results of Measurements and Analysis

The method of evaluating measurements is demonstrated by using the characteristics of the infrared thermal image in *Figs. 5* and *7* [6]. The emissivity of the insulating material is defined first.

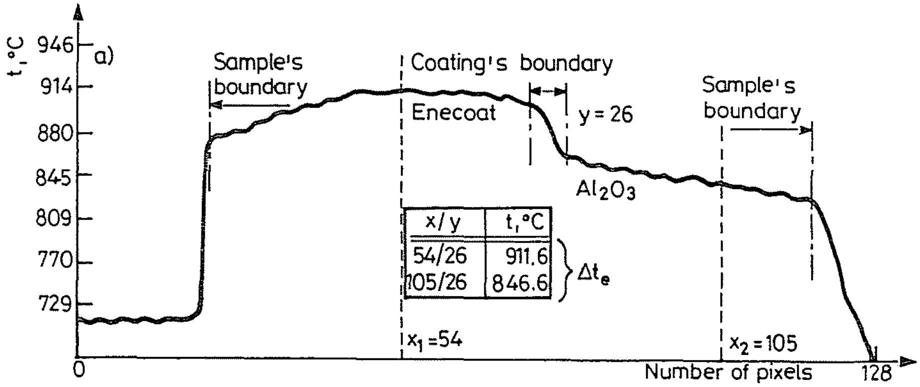

Fig. 7a. Temperature curve presented at the bottom part of *Fig. 5*

Emissivity of Ceramic Fibre

In these tests, the material used was Detrick 1500/CF 1500, a hard, white, vacuum formed ceramic fibre with a density of 320 kg/m^3 and suitable for

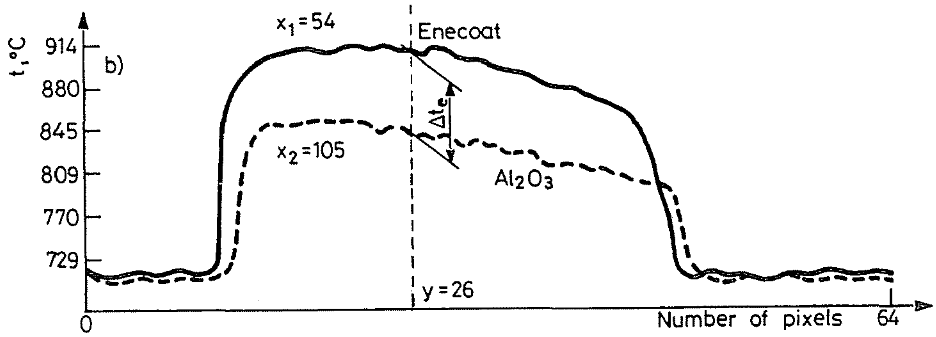

Fig. 7b. Temperature curve presented at the right side of *Fig. 5*

Emissivity of Ceramic Fibre

In these tests, the material used was Detrick 1500/CF 1500, a hard, white, vacuum formed ceramic fibre with a density of 320 kg/m^3 and suitable for temperature up to 1500 °C. The temperature of the material was measured by a thermocouple placed on the surface, and the so-called black body temperature of the radiating surface provided the basis for calculating the surface emissivity. Calculations showed the surface emissivity of this fibre to be 0.498 at 960 °C.

Comparison of Surfaces with Different Emissivities

The surface emissivity of the Detrick ceramic fibre 1500H was compared with that of Enecoat. In *Fig. 5*, two vertical and one horizontal line across the thermogram mark the cross-sections on the sample, for which temperature distribution was computed. The three temperature distribution curves are plotted on the right-hand side and bottom of *Fig. 5* for the respective cross-section, and redrawn in a graph in *Figs. 7a* and *b*. The temperature between the two curves in *Fig. 7b* is nearly constant at about $\Delta t_e = 65-70$ °C. This is the difference between the area coated with Enecoat and the uncoated surface and shows that the Enecoat directly increases the infrared emissivity of the material. Numeric values for the temperature represent the so-called 'effective black body temperature'.

Table 2 shows that the Enecoat emissivity ε_1 at 960 °C reaches values in the range 0.63 to 0.56 on the examined sample, and that the infrared radiation has increased by 12 to 27 %.

Table 2
Enecoat emissivity ε_1 at 960 °C

		Location		Average
		centre	boundary	values
Effective black body temperature (Enecoat)	t_1[°C]	909	910	891
Effective black body temperature (Detrick)	t_2[°C]	839	876	836
Temperature difference	Δt_e[K]	70	34	55
Temperature ratio	T_1/T_2 [1]	1.063	1.030	1.0496
Emissivity ratio	$\varepsilon_1/\varepsilon_2$ [1]	1.27	1.12	1.21
Emissivity (Enecoat)	ε_1 [1]	0.63	0.56	0.6

Application Guidelines

Although a considerable improvement in the emissivity of high temperature surfaces can be achieved with the Enecoat, its application requires skill and care. Also the furnace has to be properly assessed as to whether it is suitable to be coated.

As to operating a furnace coated with Enecoat the following should be marked. As it is well illustrated in *Fig. 8* in case of sample No. 7, coated surfaces in the furnace seem darker at the same temperature than those uncoated. It means that the practice of visually determining furnace temperature must be revised in case of such furnaces.

Besides, energy consumption of the furnaces also decreases if the same temperature is maintained, which means that control parameters of the furnace must also be adjusted to the new conditions.

How Emissivity Works in Flame Fired Furnaces

In the studied case the charge received radiating heat directly from the flame, indirectly from the wall, and it also emitted energy itself. Owing to the diversity of furnace types, it is difficult to devise a general method for assessing the emissivity of the wall.

Calculations showed that the influence of the wall emissivity on the energy reaching the charge is much dependent on the type and shape of the furnace. Calculations also showed that applying Enecoat to the internal wall surfaces of high temperature equipment increased the internal heat transmission.

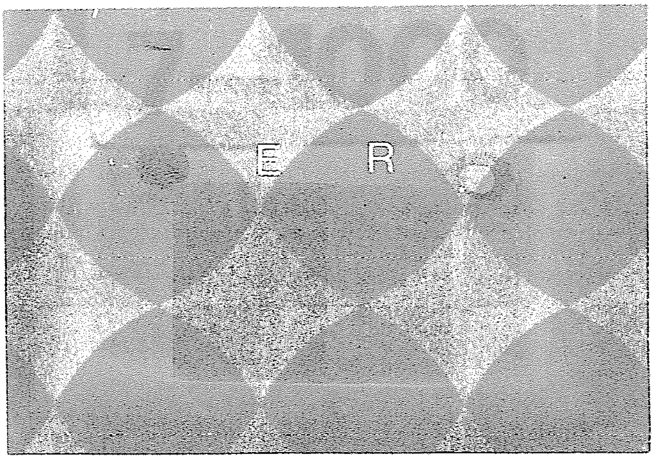

Fig. 8. The coated part (E) of sample No. 7 is darker at 1000 °C furnace temperature than the uncoated refractory (R)

Benefits of Application

Below is a list of some general improvements which may be expected. Which of these improvements will be experienced in the case of a particular furnace, will vary according to the furnace type.

(1) Improved internal infrared emissivity of furnace walls.
(2) Extended life span of the refractory lining owing to decrease in chemical corrosion and related wall erosion.
(3) Improvement in internal heat transmission, thereby reduction of the heating time.

Enecoat is important whenever ceramic fibre insulating materials are used for the internal lining because:

(1) As the temperature rises, the emissivity of fibre decreases more quickly than that of traditional refractory linings.
(2) Enecoat increases the mechanical strength of the surface of the ceramic fibre.
(3) Enecoat promotes and ensures a gastight internal surface of the furnace.

Examination of Enecoat applied to a range of Hungarian refractory materials continues within the framework of the National Research Project OKKFT G/4–V.7. According to the current findings, it appears that application of the Enecoat is also beneficial in case of silicate-based refractory materials.

Conclusions

The introduction of most methods of improving efficiency and decreasing energy consumption in furnaces is expensive and time consuming. However, improvement in heat radiation from the furnace walls can be achieved at low cost during regular maintenance periods, and can improve the internal heat exchange by 15 % to 25 %, or even more in some instances.

Another benefit is that the life span of the furnace lining is extended and the thermic inertia is decreased. As a result, the heating time will shorten. Enecoat is also beneficial in case of furnaces in which ceramic fibre is used; it increases strength of the fibre and improves its gas tightness.

Another advantage is that furnaces which are in use can be coated quickly and easily during shut-down.

Knowledge of the thermal impacts of furnace walls on the heated material is a basic problem of both construction and research. Reliable answer can only be obtained from experiments and industrial practice. Visual interpretation of the phenomenon, with infrared picture analysis, can help in influencing industrial experts' way of thinking.

Silicon carbide based furnace coatings, such as Enecoat, increase the surface emissivity of refractories, and yield energy savings and more homogeneous thermal effects. At the same time they increase the mechanical strength and decrease the porosity and chemical corrosion of furnace walls.

The results of this research can contribute to a wide use of Enecoat in Hungary, especially as ceramic fibre is being used increasingly for refractory linings.

Summary

Results of a Hungarian National Research Project OKKFT G/4–V.7 on industrial application and effects of Enecoat, a silicon-based refractory coating material, are presented. The basic phenomena resulting from the Enecoat application, and its thermal effects were examined at the Technical University of Budapest in case of several continuous furnaces of brick factories. The increase of heat radiation due to the Enecoat coating of refractories was recorded through infrared video recordings, as well as the effects of Enecoat's application, i.e. decrease of heat losses and better cooling of brick piles. The energy savings amounted to 4.8–6.2 % in case of natural gas fired furnaces and 3.8–4.4 % at oil fired furnaces.

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Address:

Dr. Imre BENKŐ
H-1111 Budapest
Kende u. 18
Hungary