

## Conference Paper

# Improving the Reliability of Rotary Furnace Drums By Stabilizing the Temperature Regime By Effect of Electromagnetic Fields

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## Abstract

The unevenness of the heat flow generated in the furnaces of the drums of rotary kilns leads to damage to the drum casing, which can cause premature failure. The author suggests that by deflecting the flame by applying electromagnetic fields, it is possible to prevent direct contact between the flame and the furnace drum, extending the latter's service life. In this way, it is possible to regulate the directions of movement of the heated combustion products to realize the uniform distribution of heat fluxes, as well as to regulate local temperature fields in real time. The study took into account 5 main factors of the influence of the electromagnetic field on the flame. Based on the studies, a description of a device partially integrated in the furnace is proposed. In this case, there is no significant constructive modernization of the furnace. This device is an analogue of a high-temperature fan, but has several advantages in comparison with it.

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**Keywords:** electromagnetic field, furnace, flame, heat exchange.

## 1. Introduction

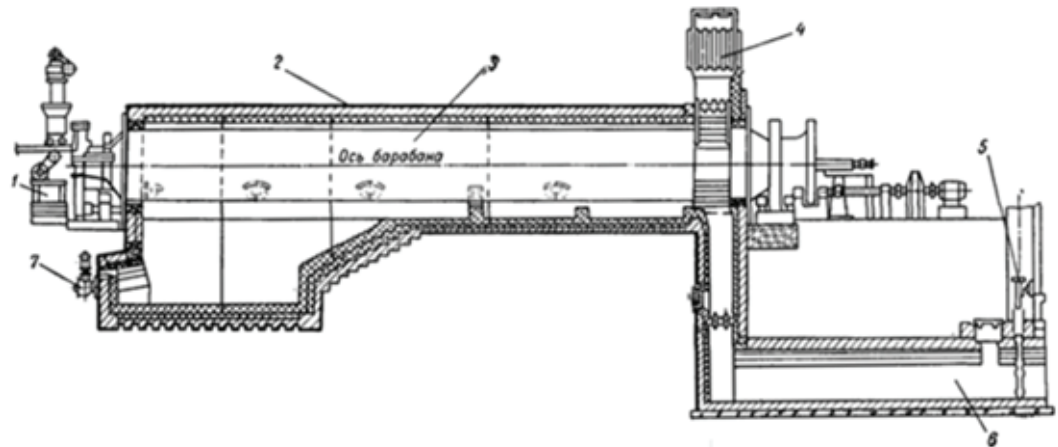
In the chemical industry, kilns of various designs and sizes are most widely used for roasting, calcining, or decomposing starting and intermediate products, the most common of which are drum rotary kilns. The developed method for stabilizing the temperature by exposure to electromagnetic fields is considered on the example of a rotary drum furnace designed for soda calcination based on natural mineral raw materials, a longitudinal section of which is shown in Fig.1.[1].

The reaction chamber is a soda furnace drum (SFD), welded from low-alloy steel sheet 32 mm thick, 2.8 m in diameter and 24.5 m in length of the cylindrical part.

On the SFD under the influence of difficult loading and operating conditions, various defects arise. A significant influence on the strength and durability of the SFD is exerted by the temperature field of the furnace body, which is characterized by a cyclical change.

The instability of temperature and power parameters is the cause of damage to the

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**Figure 1:** A longitudinal section of a soda furnace; (1) - loading mechanism; (2) - lining; (3) - drum; (4) - recuperator; (5) - shlifer; (6) - chimney; (7) - burner.

SFD in the form of ring cracks, dents, overheating of the SFD, etc., which can lead to an emergency. Increasing the overhaul period of SFD remains an urgent task today.

The flue gases produced by the combustion of fuel used to heat the SFD. As fuel, masut is used, which is sprayed through the combustion chamber of the furnace. Drops of masut when heated pass into a gaseous state, and then burn. This type of combustion is homogeneous - the fuel and the oxidizing agent are in the same state of aggregation. Homogeneous combustion is characterized by the presence of a flame in which red-hot, slightly ionized gases circulate. This makes it possible to regulate the combustion process and propagation of thermal flows through the electromagnetic field of high intensity.

In various modern furnaces, high-temperature fans are used to evenly distribute warm gas flows, capable of uniformly distributing hot gases throughout the entire volume of the unit. Their main disadvantages are:

- the presence of mechanical components affects the service life in extreme working conditions and cost
- the overall dimensions of the device complicates the installation of the fan
- high cost due to the use of materials more resistant to temperature and aggressive environments
- inability to regulate local temperature sections

In the design of this furnace, the burner flame reaches a length of several meters, and in some areas it touches directly to the walls of the drum, forming areas with the greatest heating. The use of a high-temperature fan is not able to eliminate this disadvantage without critically affecting the combustion characteristics. In the work

[1], the method of supplying fuel oil to several smaller burners was also considered, however, the overall temperature in the furnace chamber decreases, as a result of which the unit's productivity decreases.

Another reason for the uneven heating is the sticking of carbonate products to the walls of the drum, which impairs the thermal conductivity at the sticking place, and, as a result, leads to a gradual deformation of the SFD.

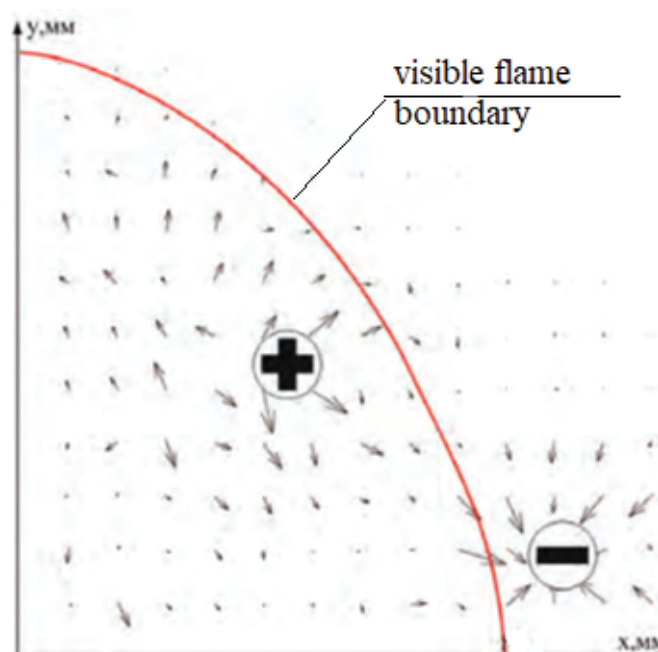
## 2. The Main Results of the Research

The proposed method is based on the effect of an electromagnetic field directly on the flame sections, thereby ensuring its deviation from the walls of the drum and exposure to gases in the furnace, which makes it possible to regulate heat by changing the direction of movement of heated combustion products, including in local zones.

Based on the literature review and the work performed, the main factors are established that affect the output parameters when an electromagnetic field affects the combustion process:

### 2.1. Polarity of radiation in the direction of deflection of the flame

The arrangement of ions of different polarity in the flame is shown in the symmetric section of the propane burner flame in Figure 2 [2].



**Figure 2:** Arrangement of ions of different polarity in a flame.

It can be seen from Figure 2 that positive ions (cations) are concentrated in the visible flame front, and they attract negative ions from the environment. It follows that the flame from the field of positive polarity will repel under the influence of Coulomb forces, and to the negative - be attracted.

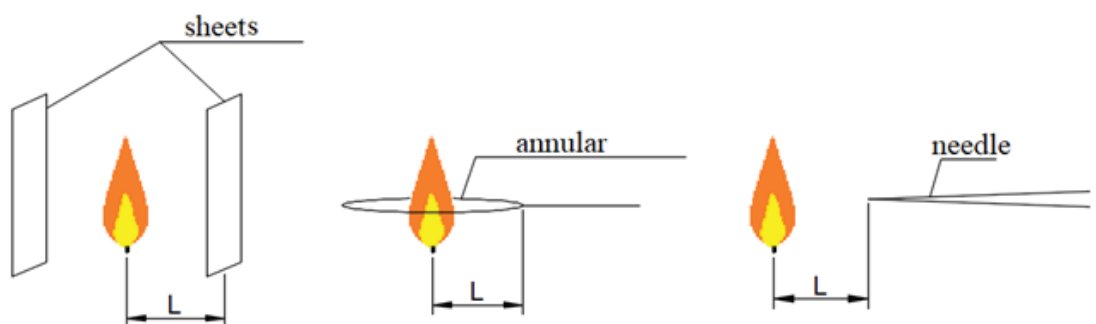
## 2.2. The shape and material of the emitter on the emission of electrons, and as a result, on the geometry of the field and flame

From the relation between the intensity  $E$ , the power flux density, and the antenna area, it can be seen that the intensity  $E$  has an inverse relationship with  $S$  [3].

$$E = \sqrt{\frac{120\pi P}{S_{\text{эфф}}}},$$

where  $S_{\text{эфф}}$  – effective emitter area;  $P$  – energy flux density in the medium.

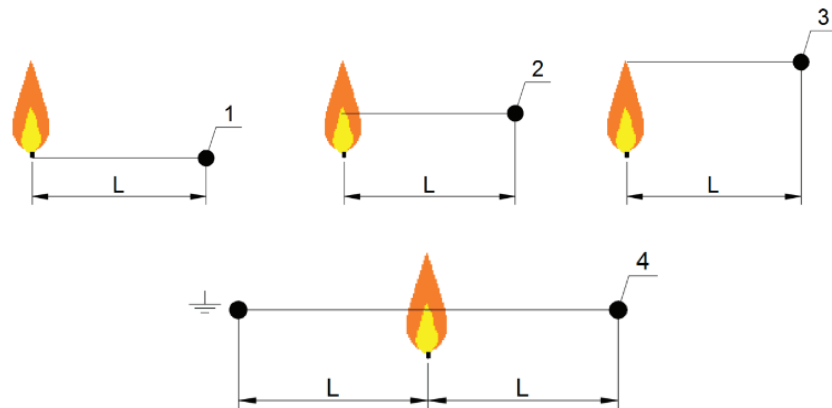
In the experiments conducted by the author, several forms of emitters were tested to identify the greatest effect on the flame (Fig. 3, Fig. 4). The data obtained in the experiments confirm the theoretical dependences. To create a directional field, the area of the emitter from the side of the subject should be minimal. However, in addition to the shape of the emitter, the configuration of the resulting field is affected by its material.



**Figure 3:** Schemes for conducting experiments with various forms of steel emitters.

## 2.3. The intensity of the electromagnetic field on the force of impact and on the speed of gas flows

The strength of the interaction of this field with the ions in the flame, and, consequently, the speed of exposure, depends on the intensity of the electromagnetic field. Eventually, the tension affects the gas flow rate under the influence of electromagnetic fields - the so called effect "ion wind".



**Figure 4:** Arrangements of needle-shaped emitters in experiments; (1), (2), (3), (4) - position of the emitter of positive polarity in height, (L) - variable distance.

## 2.4. Joule dissipation of energy for heating and completeness of fuel combustion

The transfer of part of the energy of ordered processes into the energy of disordered processes, ultimately into heat, which contributes to the intensification of the combustion process, affects the reduction in the amount of harmful emissions of products of incomplete combustion. The intensification of combustion is also facilitated by the mechanism of rupture of clots of the same charged oxygen and gas molecules using Coulomb forces, and their mixing.

## 2.5. Genus (constant or variable) and field frequency

By acting with alternating electric fields, it is possible to intensify turbulent mixing at a speed proportional to its frequency. Exposure to a constant electromagnetic field will continuously repel / attract the flow of gases in the flame.

Thus, the mechanism of the influence of the electromagnetic field on the combustion process can be expressed by the function:

$$F = f(k_1, k_2, k_3, S_{\text{эфф}}, E, E_{\text{дисс}}, f_{\text{эм.п}})$$

where  $k_1$  – coefficient taking into account the polarity of the electromagnetic field (equal to -1 or 1);  $k_2$  - coefficient taking into account the strength of the effect depending on the polarity of the electromagnetic field;  $k_3$  – coefficient taking into account the material of manufacture of the emitter;  $S_{\text{эфф}}$  – effective surface area of the emitter;  $E$  – electromagnetic field strength;  $E_{\text{дисс}}$  – dissipation energy;  $f_{\text{эм.п}}$  – electromagnetic field frequency.

For a better understanding of the mechanisms of multifactorial effects of electromagnetic fields on the combustion process requires a combination of computational and experimental studies to the correlation and regression analysis results.

Based on the studies, a description of a device for regulating thermal fields is proposed. The device is designed to be embedded in an existing soda furnace. The voltage converter block is located in proximity to the furnace unit, but so that it functions under conditions close to normal. One electrode or several electrodes are laid from the converter unit to the furnace, which connect it to a system of emitters built into the furnace unit.

By dividing the furnace volume into several zones of influence, it is possible to organize the regulation of heat fluxes in the most problematic areas of the drum. This will allow you to adjust the temperature distribution in real time with factors such as carbonate products sticking to the drum walls. Such a mode of heat distribution may help to improve the quality of processing of raw materials.

## Findings

Advantages of the proposed method:

- by changing the direction of movement of the heated combustion products by means of electromagnetic radiation, it is possible to realize the uniform distribution of heat fluxes throughout the entire volume of the unit and to regulate the local temperature fields of the furnace unit in real time (when carbonate is adhered to the walls of the drum);
- in the case of the furnace unit itself, it is possible to place only electromagnetic field emitters, which will allow not to make significant changes to the design of the existing furnace;
- the voltage converter is located outside the furnace unit (in contrast to the fan), where it will function under normal conditions, which helps to extend its service life.

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