Considering adaptation of electrical ovens with unit-type releasing to peculiarities of thermal energization of mineral raw materials

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Abstract. The paper gives a short overview of technologies of mineral raw material thermal treatment where application of electrical ovens with unit-type releasing is possible. Efficiency of such ovens for vermiculite concentrate and conglomerate roasting is proved by more than 13-years experience of their industrial operation. The paper furthermore considers alternative connections of energotechnological blocks of an oven in order to determine its efficient design for specific technology related to one or another mineral raw material.

1. Introduction
The first electrical ovens with unit-type releasing appeared in Russia in the beginning of 2000s [1, 2] and were used for expansion of vermiculite concentrates and conglomerates of Kovdorski, Tatarski and Koksharovski deposits [2, 3, 4]. Over the years ovens have been improved; their reliability increased while roasting energy intensity went down. The ovens proved to be usable for obtaining expanded vermiculite from vermiculite conglomerates [5], raw material containing vermiculite in weight fractions ranging from 30% up to 70% with associated sands and granulated materials of various mineral composition.

In 2015 there was tested an oven with an additional nonelectrical unit which decreased energy consumption on the account of inner energy of not finally expanded vermiculite [6]. Tests were carried out on vermiculite-sungulite conglomerates.

Waste of Kovdorski deposit contains millions of tons of vermiculite and sungulite [7]; the latter turns into an effective chemical for detoxification of technogenerously polluted soils and water objects [8]. The technology of their dividing was developed [9] but now it incorporates the processing step on thermal energization of the parent raw material.

Such properties of electrical ovens as compactness and light weight, low energy intensity, simplicity of design and use allow extending the field of their application in diverse technologies. Let’s consider some of them.

2. Experimental
Experimental researches established [10] that thermal activation of quartz sand and plagiogranite by temperature range of 500-650°C promotes decrease of their radioactivity on the account of diffusion processes of radionuclides. Radon maximal emanation occurs under temperatures of endothermic effects induced by dehydration and structural phase transformations in minerals. Thermal treatment considerably decreases the level of natural radioactivity of different minerals used in building that
ranges from 5-6 Bq/kg for sands up to 420-440 Bq/kg for plagiogranite and improves ecological properties of building products.

Potassium sulfate is an important fertilizer. Main source of potassium is $\text{KCl}$ extracted from sylvinite or other potassium-containing ores. It is produced as a powder with further granulation through pressing. As the results, the so-called fertilizer mixtures are obtained [11]. Authors have suggested and experimentally investigated the method of hardening of such granules. Thermal treatment within temperature range of 300-350°C is an efficient hardening method preventing them from further wear. This is one more promising field of application of electrical ovens with unit-type releasing.

Experiments described in the work [12] show that it is possible to increase the volume of hydraulic binders with the help of composite substances with application of waste products. It will allow reducing consumption of clinker in cement and obtaining materials with considerably new properties. Waste of Korkinski coal deposit hosts large amounts of opal-cristobalite rocks. Their thermal energization within the temperature range of 500-900°C results in considerable increase of binders’ strength.

The authors’ activity is aimed at the solution of one of urgent tasks such as obtaining of binding materials from industrial waste. Our ovens can serve the purpose as the basis of the considered technology.

The research team of the Institute of Chemistry and Technology of Rare Elements and Mineral Raw Materials of the Kola Science Center of the Russian Academy of Sciences has developed the method of water treatment from acidulation and ions of heavy metals [13]. The characteristic of the invention lies in the fact that chemical for water treating is the product with the content of serpentine minerals of 80-95% by mass, particle size of 0.00002–0.0002 m by the consumption of chemical within the range of 0.1–15.0 kg/m$^3$. Before water treatment, the chemical is subject to thermal activation within the temperature range of 650-820°C.

An electrical oven with unit-type releasing constructed as a sequence of inclined electrical and nonelectrical units enables thermal processing of serpentine minerals. Within the framework of the agreement with the above-mentioned institution, the team of the Technopark of Irkutsk National Research Technical University under the supervision of doctor of technical sciences Nizhegorodov A.I. has developed, produced, tested and carried out start-up and adjustment operations for the pilot...
oven at the laboratory of the institute (figure 1). This field seems to be one of the most promising for the application of ovens with unit-type releasing.

We have made a short overview of technologies for application of not only ovens with unit-type releasing but ones with moving bottom platform [14].

3. Result and discussion
The thermal activation time for different minerals considerably varies: it ranges from 2 to 3 sec by vermiculite roasting while thermal activation of serpentine minerals takes from 15 to 20 sec. If the size of processed granulated solids lies in the range of 0.001–0.005 m, the time interval stays as a rule within the mentioned limits.

The authors have developed a concept of an alternative electrical oven with unit-type releasing composed of a set of energotechnological blocks, one of which is demonstrated on the figure 2.

![Figure 3. Energotechnological block of an oven with alternative structure](image)

As shown on the figure 3, the block consists of electrical units 1 (x) with thermal lids 2 and fixing heads 3. Perforated suction tubes 4 through pipelines 5 are joined to heat chambers of an additional unit 6 (y) by pipes 7 while pipes 8 connect these chambers to an exhaust fan (not depicted on the figure 3). Points a and b correspond to the input of raw material and the output of half-finished or finished product.

Hot air passes through heat chambers creating vacuum flask effect due to which high temperature is kept in slit-like space of the unit 6. Here the exchange of heat flows takes place: the energy of small grains in the form of radiant fluxes is being transmitted to greater grains that haven’t been fully heated. At the same time the heat of surface layers of greater grains conductively passes to their deeper layers.

So, for the vermiculite by weighted-mean nominal diameter of a not finally expanded grain equal to \(D = 0.0042\) mm, the time of temperature equalization on the periphery and in the center will be 1.2 sec in accordance with the following expression:

\[ \tau = 0.677 \frac{\delta^3}{\chi} \]

(\(\delta = 0.5D, \chi\) is the index of thermal diffusivity along flakes).

But for other minerals this time can be considerably longer taking into consideration particle fineness.

The combination of electrical and additional (nonelectrified) units for the mentioned block can be expressed with the formula \(2x + y\). For the oven depicted on the figure 1 the formula takes the form \(3x + y\), while the time of material movement through the oven is equal to 3.2 sec.
The time can be increased up to required values via the efficient combination of elements of the basic block \((y \text{ and } x)\) so that work material is “fed” with heat energy from outer source as it moves; for instance:

\[(2x + y) + (1x + y) + (1x + y) = 7.8 \text{ sec,} \]

or:

\[(2x + y) + (x + 2y) + (x + 2y) = 11.1 \text{ sec.} \]

Some materials [8] require soaking for several minutes after thermal activation. Such processing chain should include a heat-insulated bin with a heating “jacket”.

4. Conclusion

Study of capacities of such energetechnological equipment for thermal energization of different materials has been recently started. It is necessary to carry out experiments on thermal activation of above-mentioned and many other minerals as well as materials of technogenic origin.

Ovens with moving bottom platform [14] developed by the research group have similar adaptive capacities. But it is another alternative requiring particular consideration.

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