Analysis of the production of lightweight refractories shows that the technology is laborious, energy-consuming, and in most cases far from optimal. This is largely because until now the foam method has been the main approach; this is very complicated, and there have been almost no advances in improving the simplest and most promising method of burning out the additives. The delay is connected with the belief that it is impossible to obtain articles with a porosity above 65% with this method. The traditional theoretical view on drying highly porous bodies, as that on the removal of water for slaking merely by evaporation, has led to the use of prolonged drying cycles (2-5 days).

A series of articles in future issues of this journal will deal with projects aimed at converting the production of lightweight refractories to a single technological procedure, using the self-densification method. This can be used with appropriate corrections for any type of lightweight parts that has a highly porous cellular or cellular-fibrous structure.

We present the theoretical principles of the method. Over many decades the science of highly porous refractories has involved the following problems: during removal of excess water added to the molding body, for the purpose of conferring the required fluidity (mobility), to reduce energy expenditure on its evaporation as much as possible, to reduce the heating time, to reduce the shrinkage during drying, and to increase the product quality.

At a certain stage in the researches a number of methods were proposed to reduce the original water content of the bodies (vibration, extrusion, chemical additives, etc.). We propose a different approach to solving this problem based on the hypothesis of rapid removal of excess moisture, not by evaporation, but by forced expulsion through thermal action on the mobile systems, included in a rigid perforated volume. In this case, the decisive factor becomes, not the initial moisture content of the body, but the excess water remaining after the removal process.

In our view the basis of the method should be the technological procedure involving the combustible additives method. Conventional combustibles (sawdust, coke, etc.) are unsuitable for making goods with a low apparent density. Researchers explain this in different ways; the influence of the grain shape of the combustibles and their surface has not been properly studied. Furthermore, it is clear that the nature of the surface, the shape of the grains, and the porosity, and hence the properties of the lightweight goods are interlinked. With the use of conventional combustibles the surface of the pores proves to be "pimply" and rough. As a result of the irregular form of the additive grains, the membrane becomes curved, and body particles are pushed out. The large volumes of capillary porosity, inherent in casting technology, also lead to a marked deterioration in the properties of the goods, especially in their strength.

Thus, the result of the low strength in lightweight refractories based on conventional combustibles is that they have an imperfect micro- and macro-structure.

Optimization of the structure should therefore be looked for in new types of combustibles evaluated by the specific surface and the geometric form of the grains. The first factor determines the consumption of refractory component needed for creating a monolithic framework, the second — the total porosity of the system. These conditions can be satisfied by an additive with particles of regular, spherical shape with the minimum surface area (roughness). Obtaining an ideal surface and a spherical particle from conventional combustibles is impossible. Foamed polystyrene of fraction <0.5 mm (polystyrene dust), which is screened out during porous plastics production, is a very effective additive.

The essence of the method is as follows. A blade mill is charged with the partly foamed polystyrene, slaking water is added, and then the dry components, followed by blending. The finished mixture with a water content of 40-50% is used
to completely fill the volume of a rigid, perforated mold; the lid is placed in position and the filled mold heated. At a temperature above 80°C the polystyrene begins to foam. The resulting forces that develop (0.2-0.3 MPa) cause up to 70-80% of the liquid to be removed from the mold, and the system is densified by the same volume; any shape of product can be stamped out. After foaming of the polystyrene is completed the mold is opened, and the greenware on the base is sent for drying, and then firing.

Removal of the liquid from the self-densifying system is accompanied by filtration processes, a knowledge of which is necessary in selecting the production schedule.

The filtration process in water transfer as a whole can be described as follows. The force of expansion in the polystyrene is transmitted, and distributed through the layer of the mineral component filling the entire intergrain space of the mixture. Under the action of this force, free water is expressed from the pore cells and capillaries, and this contributes to the drawing together of the solid particles, as a result of which the mixture is compacted. However, the expulsion of the water is gradually discontinued, since as the density of the membrane increases and the channels contract, the resistance to the movement of the water in the mixture increases up to its complete cessation (with the advance of equilibrium between the hydrostatic pressure and the resistance to the movement of the water).

An important role in self-densification and filtration of the liquid through the porous system is played by the temperature gradients developing in the volume in relation to the form of the energy source under whose influence the polystyrene is being foamed.

We studied the various ways in which the heat energy behaves towards the self-densifying bodies:

- all-round heating with hot air or steam, when the foam-spreading front of the body moves from periphery to center;
- monolateral heating with the filtration direction toward the side opposite to the pressure spread in the bodies. Here the foam-spreading front of the system is directed from the hot surface to the cold;
- monolateral flow of heat with the direction of the filtration current toward the pressure spread. The foam-spreading front of the body coincides with the direction of moisture movement to the periphery;
- electric heating. The temperature in the center somewhat outruns that of the peripheral layers.

For each of the above cases we note clear periods for the changes in water removal. It was found that the mechanism of water removal consists of a hydrodynamic process of filtration of liquid from one layer to another, continuing until the entire physically bonded water is forced from the article and equilibrium is restored between the internal and external (rigid mold) forces.

Within the moisture forced from the body there is an increase in the concentration of refractory component of the membranes, and a compact spatial packing of all the solid phase is created, leading to an increase in its strength.

A study of the graphs plotting the stress distribution, photographing them, and determining the quantitative values during thermal action on the refractory-polystyrene mixture were carried out by the polarizing-optical method and by modelling the self-densification on specially designed compression apparatus (odometer) by loading the mixture being studied, using a schedule corresponding to the change in pressure from the foaming of the polystyrene in a closed volume. The relationships were obtained for the change in pore pressure and stress in the framework of the mixture in time and over the depth, and also the relationship for the magnitude of the densification of the mineral component.

The existing rules of filtration describing the movement of a liquid under pressure through porous media do not apply for self-densifying systems, since there are constant changes in them in relation to time, pressure, porosity, and other factors. Thus, the original object was replaced with its mathematical "copy," taking account of all features of the process being studied. The use of a dialogue with the mathematical model worked out on a computer suggested a conclusion about the general nature of the effect of all the linked parameters on the filtration and densification processes during thermal action on the mixture, and enabled us to describe the link between all variables.

The basic technology is useful for various types of material: chamotte and chamotte-free, high-alumina, corundum, which in turn can be divided according to type of structure into cellular, cellular-fibrous, reinforced, those having variable densities, and monolithic. For each of them we made an all-round investigation establishing technological cycles and new means that improve the properties compared with those obtained with conventional methods.

Lightweight refractories containing polystyrene combine the advantages of a material based on foam and the working properties of the combustible additive method. The goods have clean faces and edges and so cutting and grinding are not needed (see Fig. 1). The structure of the lightweights has low capillary porosity, high density in the interpore walls, closed pores, dense and smooth surfaces.