Three variants of the introduction of an active burning-off addition into the forming mixture for the production of high-alumina lightweight refractories are investigated. The optimum composition and drying regime are determined. The possibility of replacing 30 - 40% of finely milled KDSP powder by disthene-sillimanite sand with natural grain size is established. The method of photelasticity by “freezing” the stress state of the model is used to determine the pressure developed in the mixture. Recommendations are given on the firing rate of the green with allowance for the dynamics of polystyrene pyrolysis. Articles with improved physicomechanical properties and operating characteristics are produced.

Efficient high-alumina refractories from self-compacting mixtures have been produced on the basis of disthene-sillimanite raw material, which is a valuable and unique concentrate. Its use is important for decreasing the consumption of materials in the industry.

At present articles from disthene-sillimanite concentrate are produced by the technology developed by the Ukrainian Research Institute of Refractories [1]. The bonding component is refractory clay from the Druzhkovskoe Deposit. The foam mixtures are stabilized using methylcellulose with a concentration of 0.1% (of the mass of the dry components). The foam mixtures are dried in individual molds for 60 - 72 h. After firing at 1320 - 1350°C the Podol'skogneupor JSC subjects the lightweight articles to mechanical treatment with a 60% loss to waste.

The disadvantages of this technology consist in the complexity of the preparation of the foam mixture, the long duration of drying, the considerable air shrinkage, and the need to cut and grind the articles. This makes the production cycle rather long, and the high consumption of the scarce material increases the cost of the articles. In addition, the working conditions for the personnel are not satisfactory.

A direct consequence of the poor technology is the insufficient output of efficient heat-insulating articles with a mean density of less than 800 kg/m³ by refractory plants.

We have produced test refractories from the following materials: KDSP disthene-sillimanite concentrate, finely milled and with natural grain size (TU 48-4-307 - 74), DN-1 Druzhkovskoe refractory clay, and PSV foam polystyrene of fraction No. 5. In some experiments Kizil-Kiinskoe refractory clay and milled commercial alumina of GK grade were used.

The main components of disthene-sillimanite concentrate that contains 55 - 58% Al₂O₃ are sillimanite (53 - 55%) and disthene (35 - 37%). The impurities are zircon, quartz, etc. Milling of the concentrate intensifies the processes of sintering and mullitization and decreases the transformation temperature. Disthene transforms into mullite at 1200 - 1300°C and sillimanite transforms into mullite at 1500 - 1700°C [2].

In order to produce articles in the form of bricks of a standard size and blocks from self-compacting mixtures we prepared specially designed metallic molds. The optimum composition of the components was calculated analytically and the convergence of the calculation was checked experimentally (Table 1). The optimum molding moisture content (43 - 50%) was determined by an experimentally constructed nomogram.

The behavior of stresses created by the self-compacting mixtures was investigated by the polarization-optical method in the laboratory for stress studies of the Moscow Construction Engineering University [3, 4]. The photoelasticity method is based on the capacity of some transparent materials for birefringence due to the stresses and strains arising in them. Models prepared from such materials are loaded by forces similar to those existing in an actual structure. The optical effects (bands or isochromes) appearing under the action of these forces are observed in transmitted polarized light. Knowing the order of the bands and using the basic equation
of the method and some equations of elasticity theory we can determine all the components of the stresses at each point of the mold.

Plane models of the molds were prepared from optically sensitive material based on ED-6 epoxy resin and methyltetrahydrophthalic anhydride hardener [5]. Before testing the model, the optomechanical properties of the material were determined using calibration specimens. The models were 200 × 150 × 10 mm in size. A mixture consisting of 75% disthene-sillimanite concentrate, 15% refractory clay, and 10% partially foamed polystyrene and having a moisture content of 50% was inserted in a 114 × 65 mm opening in the middle of the model. The opening was closed tightly on both sides by perforated Duralumin plates, creating a closed volume. The model with the mixture was placed in a thermostat in which the temperature was maintained at 120–125°C, which corresponded to the chosen drying regime and the regime of "freezing" the deformation in the model. The pattern of the bands was displayed on a screen and photographed every 30 min in order to follow the quantitative and qualitative changes in the stress state of the mold in the drying process.

The bands and their values did not change after 3 h. This can be explained by the fact that the mixture was dried in this time and the polystyrene had lost its activity.

Since the load due to the self-compacting mixtures is unknown, in order to determine the stresses on the internal loaded contour we should divide them by the stresses along the x and y axes, which is possible only for the model with a "frozen" pattern of the bands. This is achieved by gradually decreasing the temperature at a rate of 5°C/h over 6–7 h. It is clear that it is impossible to "freeze" the stress state of the model in the initial stage (1 h, 2 h, etc.), because in obeying this regime the mixture remains under the effect of the drying temperature, changing its activity accordingly.

We managed to "freeze" the stress state only after 4 h and determine the stresses in the internal contour. The model with the "frozen" pattern was then processed on a coordinate synchronous polarimeter, used to determine the orders of the bands and isoclines in the cross sections of interest. The stresses in the bulk of the model and the internal contour were determined by the difference in tangential stresses.

Data obtained in processing the "frozen" pattern and a special computer routine were used to determine the stresses. We arrived at the following conclusion. In drying, the maximum contour stresses appear in the beginning of the process during the first 2 h, after which the stresses decrease by 19% in 2.5 h and by another 19% in 3 h. After 3 h of drying the nature of the stress state and the values of the stresses remain virtually unchanged. Consequently, after 3 h of drying, given that the mixture has attained the specified moisture content (under the drying condition), the articles can be demolded without danger of cracking due to expansion of polystyrene grains.

The changes accompanying heating of the disthene-sillimanite mixture were investigated using a derivatograph. Derivatograms of materials with different contents of clay (20 and 30%) and polystyrene (10 and 12%) are shown in Fig. 1.

As can be seen from the TG curve, from 370–380°C to 475–500°C the loss of mass increases sharply. This is clear from the curve describing the rate of the loss of mass too. In this temperature range the DTA curve exhibits an exothermic effect. This gives us grounds to conclude that at 370–500°C the polystyrene decomposes and is completely burnt off.

The subsequent behavior of the DTA curve is caused by the change in the properties of the mineral components (mainly clay, because the disthene-sillimanite concentrate hardly changes its properties up to 1000°C). In the 500–560°C range in the mixture with 20% clay and in the 530–570°C range in the mixture with 30% clay we observe endothermic effects corresponding to the separation and removal of the hydrate water from the clay. The mixture with the greater content of polystyrene loses mass intensely. Based on these investigations we could recommend regimes for firing the green with allowance for the dynamics of polystyrene pyrolysis.