The main advantage of using rammed mixtures to line furnaces is the absence of seams. However, this advantage is lost unless the rammed lining is prevented from cracking during drying, heating and operation due to inconstant volume shrinkage. The absence of shrinkage at the final firing temperature and at the maximum service temperature, which is sometimes obtainable by the formation of minerals with a lower specific gravity and the growth of the mixture, is not characteristic of the behavior of the mixture when heated to lower temperatures.

The good quality of refractory rammed mixtures, apart from refractoriness, density, strength and resistance to the action of reagents from the combustion chamber, requires the absence of shrinkage at all temperatures, including the maximum service temperature.

If heated, silica and semi-acid rammed mixtures exhibit growth due to modification of the quartz. Chamotte and high-alumina mixtures with an argillaceous binder, but without special additives causing their growth, show a shrinkage of 0.5-1% or more when heated to 1300-1400 °C, and cannot therefore be used at the abovementioned, or higher temperatures.

To offset shrinkage and ensure the growth of alumosilicate mixtures, it is advisable to add cyanite to them. As is well known, between 1250 and 1400 °C cyanite is converted into mullite and amorphous silica with a 16-18% increase in volume.

Study has shown that high-alumina rammed mixtures containing 14-20% fine-ground cyanite concentrate from the Khizovar deposit in the binding part exhibit quite satisfactory characteristics after firing at 1300-1400 °C, and their growth attains 0.4-0.8% (see below).

To bring about the growth of the high-alumina mixtures we synthesized “secondary” mullite from sintered corundum and clay.

This process begins at about 1300 °C and is accompanied by an increase in volume due to the lower specific gravity of the mullite (3.00-3.05) compared with that of a stoichiometric mixture of corundum and clay (3.15) [1, 2].

The mullite binder formed thereby, provided the content of mullite in the filler is high, makes the properties of the mixture as a whole homogeneous. The advantage of the mullite binder in alumosilicate refractories has been pointed out by a number of investigators [3-6]. To create this binder it is usual to add pulverized industrial alumina and clay to the binding part of the charge.

If the mixtures contain a considerable amount of industrial alumina, firing shrinkage is increased and the density of the parts is decreased. The addition of industrial alumina to the binding part in rammed mixtures would lead to increased shrinkage, and not to growth.

High-alumina mixtures containing so-called “dense-forming” alumina fired at 1450 °C show a shrinkage up to 1% at that temperature [7].

Clay begins to react with electrically melted corundum at a higher temperature than with sintered corundum. Furthermore, the cost of electrically melted corundum is higher.

Hence when preparing high-alumina rammed mixtures, corundum with the addition of 1% TiO₂ fired at 1600-1630 °C was included in the composition of the binder. Further investigation showed that when the service temperature of the rammed mixture is not greater than 1450 °C, corundum with the addition of 1% TiO₂ fired at 1500-1550 °C can also be used as an additive for the binder.

As the argillaceous component we added different amounts of Chasov-Yar CH-1 and Kirovka K-1 clay to the binder. The simultaneous addition of Chasov-Yar clay containing alkalies and kaolinite Kirovka clay caused a more intensive formation of “secondary” mullite at 1300-1400 °C than when the mixture only contained one of these clays. A composite binder made of two clays makes the mixture stronger and denser at lower temperatures than a binder made of Kirovka clay alone.

The mixtures to which we added Arkalyk hydargillite-kaolinite rock instead of clay showed greater porosity and less strength after firing at 1300 and 1400 °C.

As the filler we added high-alumina mullitized 40/60 chamotte made from industrial alumina and Kirovka clay, high-alumina chamotte A from Arkalyk rock, and chamotte K made of Kirovka clay. The chamottes made of the high-alumina variety of Arkalyk rock as well as from the Kirovka clay were used on account of the ease with which they become mullitized [8, 9], and also in order to reduce the cost.

When developing the technology for high-alumina rammed mixtures we took into account the following requirements: absence of shrinkage during service at all temperatures; strengthening at fairly low temperatures; low porosity; the formation of a mullite binder at fairly low temperatures, and we also took into account the data on the manufacture of high-alumina refractories [10-13].

The composition of the mixtures and the characteristics of the initial materials used to make them are shown in Table 2.
The chemical composition of the initial materials is shown in Table 2.

The water absorption of the fired corundum was 0.5–4.0%. Since it was used in the finely ground form, the increased porosity did not have any effect on the density of the rammed mixture.

As pointed out above, if the service temperature of the rammed mixture is not greater than 1450°C, corundum fired at 1500-1550°C may be used. Corundum fired at reduced temperatures has smaller-size crystals [7, 14], and therefore reacts with the clay component more violently, bringing about more intensive formation of "secondary" mullite and making the mixture very strong. The corundum was crushed and then pulverized successively in rolls and in a vibro-mill until at least 98% passed through a mesh with 10,000 holes per cm².

The fine-ground mixtures (see Table 1) were tempered for 2 hours in ball mills.