formation in the roof bricks of fusible calcium oxychromite (melting point less than 1174°C) and monocalcium ferrite (1216°C), contributing to the fusing of the working surface of the roof.

Spalling and fusing of the roof causes rapid wear of the lining as a result of which there is a marked fall in the structural strength of the roof, and premature demolition of the structure occurs. The first roofs which have sector-arch construction made of periclase—chromite articles MKhS-4, MKhS-13, and MKhS-34, were distinguished by high local deformation and low constructional strength, as a result of which the life was low, and in the periphery part equaled only 100, and in the central part 40-60 heats.

Consequently, to increase the resistance of the roof of the RKZ-10.5 RRN-1 furnace it is necessary to reduce the rate of wear and to increase the roof's structural strength. This may be attained by using higher grade refractories in the roof and also by using a roof design facilitating a reduction in the thermomechanical stresses forming in the structure.

With this aim, tests were carried out in the central part of the roof with periclase—chromite refractories MKhVP using fused periclase—chromite, MKhVU-51, MKhVU-62, MKhVU-63 produced by the Magnezit combine (TU 14-200-270-78) which had shown an increase in resistance in the roof to 182 heats. However, despite the increase in the resistance of the roofs, the use of such refractories for building the entire central part at the present time is ineffective because of their high cost. It is best to use them only in the maximum-wear section of the roof's central part.

To increase the resistance of the roof in the RKZ-10.5 RRN-1 furnace we developed and tested an annular design for roofs using shaped periclase—chromite articles PKhSÉ and PKhSÉ-5 produced by the Magnezit combine (TU 14-8-271-78). We thereby obtained a reduction in local deformation in the structure due to the more uniform distribution of the stresses, an increase in structural strength and an increase in the resistance of the central part of the roof to 135, and at the periphery to 203 heats.

CONCLUSIONS

The investigation of the service conditions for periclase—chromite refractories in the roof of the electric-arc furnace RKZ-10.5 RRN-1 and their examination after service established the causes of the low roof resistance, and suggested measures aimed at improving the life.

The most effective turned out to be creating an annular design for the roof using shaped articles PKhSÉ-3 and PKhSÉ-5 which at the present time are being introduced for all arc furnaces at the Chelyabinsk Electrometallurgical Combine.

A PROTECTIVE COATING FOR THE TAMPED LINING
OF INDUCTION FURNACES

I. Ya. Prokhorova, O. V. Novikova,
V. V. Lazarev, and B. I. Sergeev

Induction channel furnaces with an iron core (Fig. 1) are used in the production of a large variety of copper-based alloys; the furnace has a transformer with the primary winding mounted on an iron core and the secondary winding combined with the load as a closed ring of fused metal. When the energy circulates, the metal heated up in the ring channel, heats the metal batch loaded into the furnace shaft [1, 2].

The lining of an induction furnace with an iron core consists of a shaft tube made from refractory brick and a tamped hearthstone. This hearth is the most important part of the lining since it determines the length of the furnace campaign. It is made by a tamping of a dry refractory mass, predominantly quartzite, with the addition of 1.5-2%* of borax or boric acid [3-5].

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*Here and elsewhere, mass fractions are given.
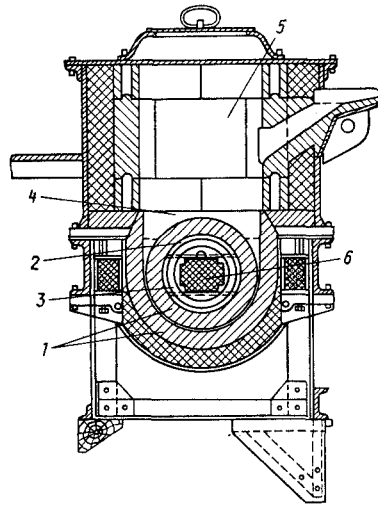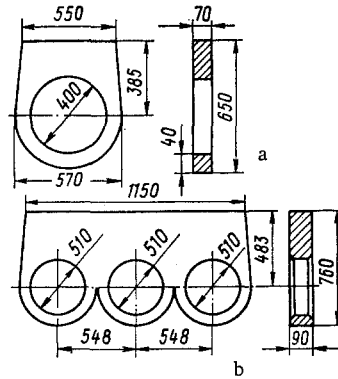

Fig. 1   Fig. 2

Fig. 1. Induction channel furnace with an iron core: 1) hearth; 2) eternit cylinder; 3) inductor; 4) smelting channel; 5) shaft; 6) iron core.

Fig. 2. Cast formers for moulding the melting channel in single phase (a) and three-phase (b) furnaces.

Cast or rolled copper formers (Fig. 2) are used to mould the melting channels in the hearth. The size of the formers is determined by the composition of the alloy to be melted in the furnace.

The hearth is heated from the autotransformer comprising the metal former forming the melting channel. The heating is done for 14-17 h.

The maximum heating temperature is determined by the temperature at which the copper former begins to melt (1083°C). Naturally, it is not possible to sinter the hearth at this temperature. When the former melts, the porosity of the refractory in contact with the metal layer is > 30% and, as a result, it can easily be impregnated by the metal which increases the chance of breakdown.

Attempts have been made to use various sintering additives to ensure that the contact layer of the hearth is sintered before the metal melts but none has proved effective since the effect of the added sintering additives is suppressed by the degeneration of quartz which begins at these temperatures. This process is accompanied by an increase of up to 4% in volume with a corresponding loosening of the contact layer.

Allowing for the behavioral features when the quartzite tamping mass is heated, we made some attempts to protect the hearth of an induction furnace from penetration by metal and for this purpose a protective coating was specially developed.

It is well known that the channel part of the furnace lining is not accessible (because of its design) to the application of a protective coating by spraying or plastering the working surface with the protective coat. It was therefore decided to apply the protective coat not to the lining but to the metal former which forms the smelting space of the furnace. The former with the protective coating was molded into the refractory tamping mass during the preparation of the hearth. While the hearth is being warmed up the metal former expands and presses the protective coating which had been applied to the refractory tamping mass thus filling up the pores (Fig. 3).

TABLE 1. Characteristics of Aluminophosphate Bonding

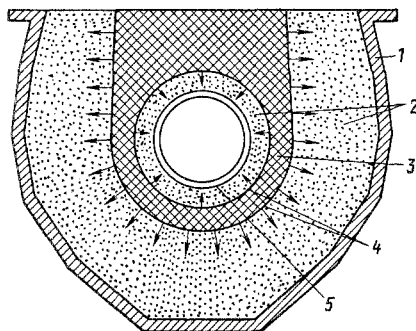| Method of preparation	Density, g/cm^3	Chemical composition, %			Extent of neutralization
		Al_2O_3	P_2O_5	l.o.i.*	
1st	1,785	15,80	55,19	28,86	28,1
2nd	1,783	16,50	54,73	28,53	31,0

*Loss on ignition.

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Fig. 3. Effect of a protective coating on the
tamping lining when the former is heated: 1)
body of induction unit; 2) hearth; 3) metal former;
4) protective coating; 5) eternit cylinder.

In developing the composition for the protective coating, we started from the following assumptions.
The bonding agent would have to be a material which would provide strong adhesion between the coating and
the metal former and the filler would have to be a refractory oxide which would participate at the working
temperature in an interaction with the SiO_2 of the tamping refractory lining, forming a metal-resistant com-
pound. On this basis we used Al_2O_3 as the filler since this forms mullite in the reaction with SiO_2.

These laboratory studies established that the best results are achieved by using coatings based on
aluminophosphate bonding containing industrial alumina (99% Al_2O_3) as the bonding agent; the latter is ham-
mered in a vibromill to a grain size of < 0.088 mm.

The aluminophosphate bondings may have quite different degrees of neutralization of the orthophosphoric
acid (N_m, %) as characterized by the ratio $Al_2O_3/P_2O_5 \cdot 100$. The binding properties depend on the degree of
neutralization. The best binding properties are found in the acid aluminophosphates with $N_m < 100\%$.

In our case disubstituted aluminophosphate, $Al_2(HPO_4)_3$, with a degree of normalization of ~30% was
found to be the most suitable. We used industrial orthophosphoric acid of density 1.42 g/cm^3 and hydrated
aluminum oxide in the form of a finely milled powder (< 0.088 mm) was used to prepare this material. The
material also contained 0.25% SiO_2, 0.005% Fe, 1.00% alkali and alkaline-earth metals, and 0.01% sulfates.

The ratio of acid to aluminum oxide hydrate (82 : 18) was selected by a trial-and-error method. The
orthophosphoric acid was heated to 80-90°C and the aluminum oxide hydrate was then stirred into it. After a
10-min dwell at this temperature the solution became tacky and transparent (method 1). A second method was
also tested for obtaining the aluminophosphate bonding without preliminary heating of the orthophosphoric acid.
In this case the catalyst for the reaction was powdered aluminum metal, grade APV, which was added with
agitation in amounts of 1% (on 100% of the basic components) to the cold orthophosphoric acid. The powdered
aluminum oxide hydrate was then poured in.

TABLE 2. Results of Tests of
Quartzite Linings of Induction Fur-
naces

Quartzite lining	No. of fur-naces	Temp., °C	Av. amount of smelted metal, tons
Smelting aluminum bronze			
With pro-tective coating	7	1120—1200	114,2
Without protective coating	9	1120—1200	69,8
Smelting melchior			
With pro-tective coating	6	1280—1300	114,0
Without protective coating	11	1280—1300	80,37

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The characteristics of the aluminophosphate bonding obtained by both methods are shown in Table 1. A filler (33%) was added to the prepared aluminophosphate. The amount of filler was chosen so that the consistency of the mass would be convenient for working. The composition of the prepared coating was as follows: Al_2O_3, 46.62%; P_2O_5, 35.81%; and loss on ignition, 16.34%.

Under production conditions we tested the method of applying the protective coating to the surface of the cast metal formers. The surface of the former was first treated with a solvent (benzene, xylene) in order to remove any greasy film. A layer of coating 1.5-2 mm thick was then applied with a flat brush. The applied layer dried easily in air at room temperature and a second layer of the coating 1.5-2.0 mm thick was then applied. The coating on the surface of the former was finally dried at room temperature for 2-3 days.

Under production conditions at the Krasnyi Vyborzhets Leningrad Planning Organization, we tested refractory linings with a protective coating during the smelting of aluminum bronze, BrAZhN-10-4-4 (9.5-11.0% Al, 3.5-5.5% Fe, 3.5-5.5% Ni, and 78-83.5% Cu), and melchior, NM-81 (18-20% Ni + Co and 80-82% Cu). For the manufacture of the hearth we used a quartzite tamping mass containing 98.5% quartzite and 1.5% borax. The chemical composition of the tamping mass was as follows: SiO_2, 94.7%; TiO_2, 0.08%; Al_2O_3, 2.18%; Fe_2O_3, 0.89%; CaO, 0.25%; MgO, 0.47%; and R_2O, 1.27%. The grain composition of the mass was: 5.67% fractions > 3 mm; 10.20%, 3-2 mm; 11.7%, 2-1 mm; 9.35%, 1-0.5 mm; 12.45%, 0.5-0.2 mm; 8.27%, 0.2-0.088 mm; and 42.11%, < 0.088 mm.

In the preparation of the lining of the furnaces used for smelting aluminum bronze we used cast copper formers of cross section 650 × 580 × 100 × 50 mm with the protective coating applied using the method indicated above. For smelting the aluminum bronze we mounted seven two-channel furnaces in which the channel section of the lining was given a protective coating.

In the preparation of the furnace linings designed for smelting melchior, we used cast copper formers of section 650 × 570 × 70 × 40 mm. Six furnaces with the channel section protected by linings were prepared for smelting the melchior. The lining for the furnaces were prepared and the heating schedule carried out in accordance with the normal plant practice.

Table 2 gives the results of the tests of furnace with a lining in which the channel region had been given a protective coating as a comparison with those furnaces melting analogous alloys but with the hearth unprotected.

The data obtained show that the use of a protective coating for the furnace linings smelting melchior show a 40% higher resistance and in the case of the furnaces smelting aluminum bronze, 65% higher resistance.

Thus, the use of protective coatings for the tamped linings of induction furnaces provides significantly higher resistance to attack and the process can also be recommended for the tamping lining of crucible furnaces made with a metal former.

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