SERVICE OF PERICLASE—CHROMITE REFRACTORIES IN THE ROOF OF A FERROALLOY ELECTRIC-ARC FURNACE

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At the Chelabinsk combine they are operating RKZ-10.5 RRN-1 electric-arc furnaces for smelting ore-lime melt which is used to obtain low-carbon ferrochromium. The roofs of these furnaces having a diameter of 6950, radius 7158, and lining thickness 380 mm are made of periclase—chromite refractories.

During service the lining of the roof is subject to the action of high temperatures which change during the melting period and are irregularly distributed over the working surface of the roof. Variations in temperature in the subroof space are caused by batch charging, which occurs continuously through the aperture located in the central part of the roof. As a result of such charging, the rate of which alters during the melting period, the surface of the melt remains completely open only at the end of the melting for 10-20 min before discharge of the melt, and for the rest of the time half of its surface is covered with batch.

The temperature schedule for working the lining of the RKZ-10.5 RRN-1 furnace was studied by measuring the temperature of the roof working surface. Measurements were made with VR 5/20 thermocouples placed in the aperture located at a distance of about 1 m from the phase, flush with the working surface of the roof. A secondary instrument was used in the form of a galvanometer. The temperature was measured after various intervals over a period of several heats. It was found that the temperature of the working surface in the roof during a heat varies from 1350 to 1750-1800°C, reaching a maximum value at the end, when batch charging is discontinued and the melt surface remains completely open.

Together with the high temperature at the working surface, harmful action comes from the furnace dust containing 40.33% CaO, 15.22% Cr_2O_3, 8.91% MgO, 2.96% SiO_2, 4.02% Fe_2O_3, 2.95% Al_2O_3, 2-3% K_2O. The refractoriness of the furnace dust is 1310°C.

TABLE 1. Chemical Composition of PKhS Refractories after Service in the Roof of the Electric-Arc Furnace

Zone	Zone thickness, mm	Weight,* %										
		SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	P_2O_5	Cr_2O_3	K_2O	Na_2O	loss on ignition
Refractory No. 1												
Working	25	2,26	3,55	8,98	not det.	18,20	44,92	0,09	21,66	0,03	0,31	0,56
Transition	70	4,14	1,80	8,74	6,18	4,64	65,52	0,04	8,87	0,03	0,55	wt. increase
Least-changed	83	3,82	2,24	4,11	1,84	2,68	74,43	trace	9,53	0,13	0,84	0,70
Refractory No. 2												
Working	35	2,14	2,85	5,53	not det.	18,92	46,15	not det.	23,96	0,03	0,38	0,54
Transition	95	7,56	2,63	2,18	1,92	8,30	66,40	0,04	9,43	0,06	1,20	0,66
Least-changed	155	6,36	2,30	3,22	0,84	2,20	74,88	not det.	8,69	0,04	0,75	0,68

*All zones of the refractories contained traces of TiO_2.

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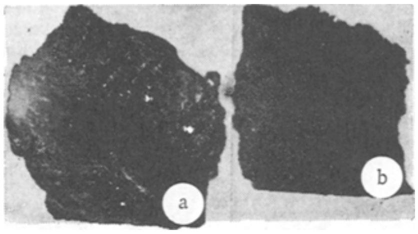

Fig. 1. Refractories PKhS No. 1 (a) and 2 (b) after service in the roof of an electric-arc furnace RKZ-10.5 RRN-1 (reduced 5 times).

Investigations of the composition of the gas phase in the working space of the furnace carried out with the VTI-2 gas analyzer placed in the aperture in the roof, designed for thermocouples, provided the following (averaged per heat) composition, % (parts by volume) CO_2 2-5.6, O_2 12-18, CO up to 1.5, H_2 up to 1.6, CH_4 up to 0.4; and the remainder — N_2. The composition of the gas phase indicates an oxidizing atmosphere, which usually does not have much effect on the furnace lining.

In order to study the conversions occurring in the periclase—chromite bricks during service, we carried out a chemicomineralogical study of two articles. They were selected from the center of the roof at the end of the campaign lasting 56 heats. Refractory No. 1 was located in the joint of the central arch and the crosspiece, and refractory No. 2 — in the wall of the electrode aperture (phase I) on the peripheral section. The residual length of the refractory No. 1 was 179, No. 2 — 286 mm. The articles after service are shown in Fig. 1.

Investigations showed that during service the PKhS bricks undergo chemicomineralogical and structural changes, as a result of which three zones are formed: least changed, transition, and working. The changes in chemical and mineral compositions of these materials across the zones are shown in Tables 1-2.

TABLE 2. Mineral Composition of PKhS after Service in Arc Furnace Roof

Zone	Volume parts, %*		
	periclase	chrome spinel	monticheIlite (forsterite)
Refractory No. 1			
Working	40	24	3†
Transition	64	22	14
Least-changed	70	20	7,5(2,5)
Refractory No. 2			
Working	40	22	4†
Transition	60	20	16
Least-changed	66	18,5	6(9,5)

*In working zone of No. 1 the parts by volume of dicalcium silicate (α and β-$2CaO \cdot SiO_2$), monocalcium ferrite ($CaO \cdot Fe_2O_3$) and calcium oxychromite ($9CaO \cdot 4CrO_3 \cdot Cr_2O_3$) were, respectively, 8.8 and 17%; for refractory No. 2 — 9, 11, and 14%. In the transition zone of No. 2 refractory there is also 3% α and β-$2CaO \cdot SiO_2$, and 1% $CaO \cdot Fe_2O_3$.

† Indicates the parts by volume of merwinite ($3CaO \cdot MgO \cdot 2SiO_2$), %.

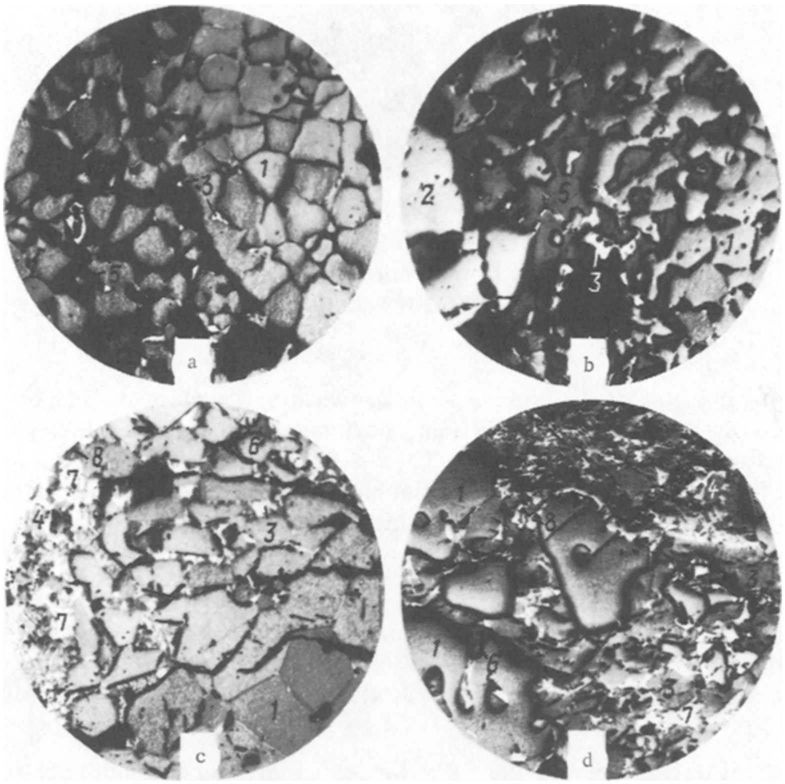

Fig. 2. Microstructure of PKhS refractory after service in the roof of arc furnace RKZ-10.5 RRN-1; a) least-changed zone, b) transition zone, c) working zone, d) site of contact between refractory and slag, 1) periclase, 2) chromite, 3) chrome spinel, 4) dicalcium silicate, 5) montichellite, 6) merwinite, 7) calcium oxychromite, 8) monocalcium ferrite; dark areas — gaps and pores, ×80. Reflected light.

The least-changed zone consisted of coarse (up to 2 mm) dense aggregates of brownish periclase grains and fine-grained porous bonding mass, dark brown in color (Fig. 2a). The aggregates consist of dense growths of mainly angular grains of periclase measuring up to 0.08 mm, in the main 0.06 mm, with continuous films of silicates — montichellite and forsterite. The peripheral grains of periclase in the aggregates contain very fine inclusions of magnesioferrite, $MgO \cdot Fe_2O_3$, which are the product of decomposition of the solid solution.

The bond consists of broken grains of periclase of rounded form measuring up to 0.05 mm, grains of chrome spinel, most often of irregular shape, mainly in direct intergrowth with grains of periclase and montichellite, fulfilling the role of cement. The grains of periclase contain inclusions of magnesioferrite.

Approaching the working surface in the zone we note a more complete exchange of oxides between the periclase and grains of chrome spinel. The periclase is more uniformly saturated with iron oxides to form magnesioferrite.

The transition zone is characterized by concentrations in it of silicates, mainly montichellite migrating from the hot zone as recrystallization through the original cavities and pores, and the commencement of recrystallization of periclase grains.

The transition zone preserves the relict structure of the least-changed zone and has a dark-brown color. It includes aggregate growths of grains of periclase measuring up to 0.07 mm with films of montichellite and forsterite, fragments of chromite and bond (Fig. 2b). The bonding mass consists of embrittled grains of periclase measuring up to 0.06 mm, grains of chrome spinel, cemented with montichellite. The pores are closed, rounded in shape, and measure up to 0.13 mm in diameter.

The working zone is characterized by recrystallization of the periclase grains. The size of the periclase aggregates increases to up to 0.16 mm. The grains of periclase acquire a polygonal shape and contain pores. The silicate films are almost absent. Cracks form in the aggregates of growths of periclase.

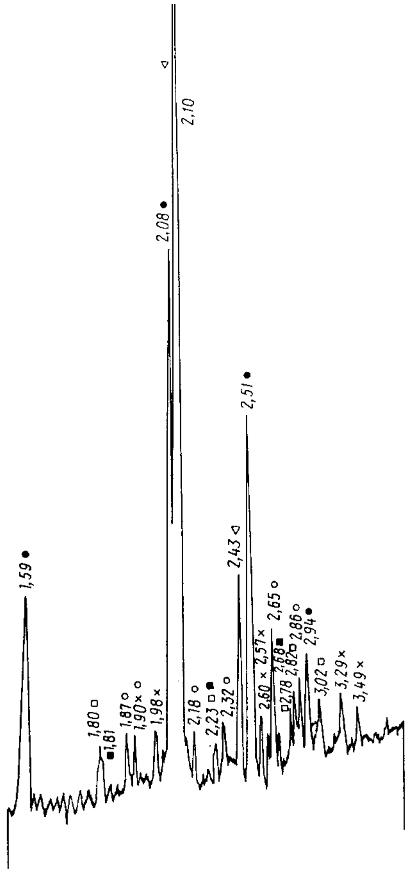

Fig. 3. X-ray patterns of working zone of PKhS refractory. ▽) periclase; ●) chrome spinel; ×) $9CaO \cdot 4CrO_3 \cdot Cr_2O_3$; ○) $3CaO \cdot MgO \cdot 2SiO_2$; □) α- and β-$2CaO \cdot SiO_2$; ■) $CaO \cdot Fe_2O_3$.

The bond mass consists of grains of periclase, and relicts of grains of chrome spinel cemented with merwinite. Closer to the working surface the aggregates of periclase grains are broken down. The grains of periclase are separated by the merwinite and glassy substance, partially dissolved, and they contain rounded pores. Closer to the working surface the silicates are replaced by grains of di- and tricalcium silicate of elongated form intergrown with the films of $CaO \cdot Fe_2O_3$ and separations of anisotropic $9CaO \cdot 4CrO_3 \cdot Cr_2O_3$ of irregular form (Fig. 2c).

The working wavy surface of the refractories is covered with a dense slag skin black in color and up to 1 mm thick. It consists of grains of $3CaO \cdot SiO_2$ measuring up to 0.03 mm, very fine continuous films of monocalcium ferrite, grains of ferrochrome spinel measuring up to 0.025 mm, odd grains of periclase from the refractory, and needles up to 0.008 mm in cross section, probably calcium chromite β-$CaO \cdot Cr_2O_3$ (Fig. 2d). On the working surface of the refractory there are icicles (weight parts of MgO 61.49%, Cr_2O_3 16.6%), whose length sometimes reaches 50 mm.

X-ray analysis* of the working zone confirmed the presence in it of periclase (2.43, 2.10), chrome spinel (2.94; 2.51; 2.08; 1.59), $9CaO \cdot 4CrO_3 \cdot Cr_2O_3$ (3.49; 3.29; 2.60; 2.57; 1.98; 1.90), $3CaO \cdot MgO \cdot 2SiO_2$ (2.86; 2.65; 2.32; 2.18; 1.90; 1.87), α- and β-$2CaO \cdot SiO_2$ (3.02; 2.82; 2.78; 2.23; 1.80) and $CaO \cdot Fe_2O_3$ (2.68; 2.23; 1.81) which is seen from Fig. 3.

The high temperature of the underroof space which alters during the melting cycle and is irregularly distributed over the internal surface of the roof, as in steel melting arc furnaces, causes irregular distribution of the thermomechanical stresses in the roof structure, giving rise to local deformation which leads to scaling of the roof bricks. A feature of the service of the roof in the ferroalloy arc furnace RKZ 10.5 RRN-1 is the action on its lining of furnace dust with a high concentration of calcium and chromium oxides, leading to the

* Completed by L. S. Zholobova.

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

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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].

*Here and elsewhere, mass fractions are given.

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