CERTAIN RULES OF FORMATION OF THE BLOCK IN MELTING BRUCITE IN AN OKB-955N SMELTING FURNACE

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To obtain fused periclase using the block process, OKB-955N three-phase smelting furnaces with high power (1200 kVA) transformers are used. However, calculation methods which would relate the technical characteristics of the furnaces to the composition of the material charged in the furnace, the electrical and thermal conditions of melting, features of heat and mass exchange in melting, and the quality of the finished product are lacking.

Therefore, the optimum furnace parameters and melting conditions are selected experimentally, taking into consideration the composition of the charge and the quality of the finished product.

The furnaces for the block process are not lined since the layer of unfused charge which always remains between the shell and the molten material serves as the lining.

In the cross section of the block the fused portion of the periclase forms a triangle with apexes rounded at the radius of the electrodes (Fig. 1), while the remaining significant portion of the furnace space is unfused charge in the form of a sintered crust and screes. Therefore, the selection of means of increasing the quantity of the fused portion of the block and, consequently, increasing the technical and economic indices is one of the basic problems of research work in the area of production of fused materials using the block process.

It was necessary to determine some of the rules of the formation of a block in the melting of brucite and solidification of the molten material. For this purpose temperature measurements were made in the layers of the unmelted charge and in the thicknesses of the zones formed of the blocks.

Fig. 1

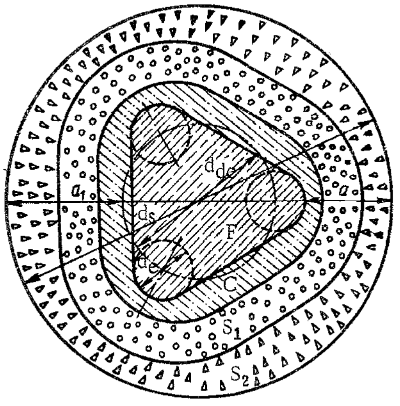

Fig. 2

Fig. 1. General view of the fused portion of perclase in the cross section of the block: 1) fused portion of the periclase; 2) sintered crust.

Fig. 2. The relationship between the furnace parameters d_s, d_e, and d_{de} and the formation of zonality in the cross section of the block: d_s, d_e, d_{de}) diameters of the furnace shell, the electrodes, and the decomposition of the electrodes; F, C) fused portion of the block and crust; S_1, S_2) screes in the form of dehydrated and raw brucite, respectively; a, a_1) unfused portion opposite the electrode and interelectrode zones of the block, respectively.

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TABLE 1. Dimensions of the Zones and Temperature Gradients in the Cross Section of the Block

Series of heats	Furnace shell diam., mm	Average rate of fusion of the block (mm/h)	Location of the zones of the block	Dimensions of the zones, mm				Temperature gradient, °C/cm		
				radius of the fused portion	thickness			in the crust	in the screes	
					sintered crust	screes S_1	screes S_2		S_1	S_2
First	2800	37	Between the electrodes	400	350	250	380	37	31	9
			Opposite the electrodes	500	250	200	250	52	43	14
Second	2500	30	Between the electrodes	500	300	270	180	43	40	20
			Opposite the electrodes	650	230	240	130	56	47	25
Third	2500*	25	Between the electrodes	500	300	250	200	43	36	17
			Opposite the electrodes	700	250	230	70	52	43	40

*Shell with water cooling system.

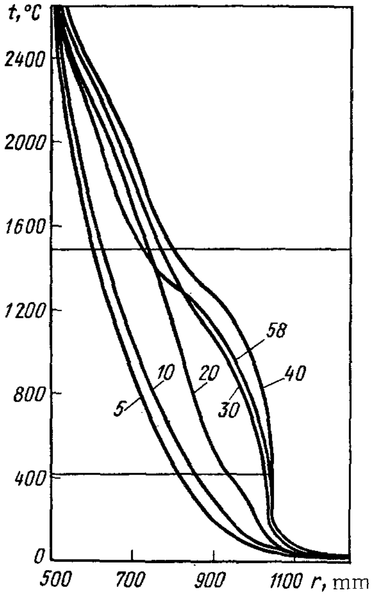

Fig. 3. The distribution of temperatures t in the layers of the charge in the radial direction from the vertical axis of the block to the furnace shell: r) radius of the layer; numbers at the curves) time from the start of melting, in h; upper and lower horizontal lines) isotherms of fusion of monticellite and dehydration of brucite, respectively.

Three series of heats were melted with measurement of the temperatures* in the layers of the charge and the thicknesses of the zones formed. The first series of heats was melted in a furnace with a shell diameter d_s of 2800 mm, and the second and third series, in a furnace with d_s of 2500 mm. In the third series of heats the furnace shell was water cooled. The thermocouples were placed in the layers of the charge at three levels from the shell in the interelectrode zone at depths of 250, 350, and 450 mm and in the zone opposite the electrode at depths of 200, 250, and 300 mm. The designations and character of zonality in the cross section of the block are shown in Fig. 2. The characteristic temperature distribution in the layers of the charge is shown in Fig. 3, and the dimensions of the zones and the calculated temperature gradients are given in Table 1.

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*The temperatures were measured by M. K. Kolchinyi, D. I. Kirzhner, and V. N. Koptelovyi.

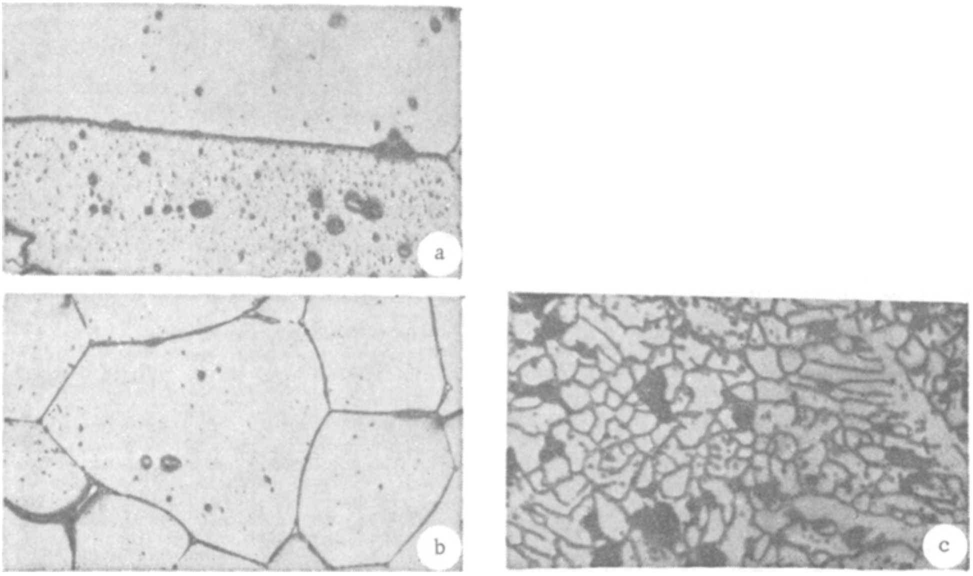

Fig. 4. The characteristic microstructure of directed columnar (a), three-dimensional polycrystalline (b), and dendritic (c) crystallizations of molten periclase: a, b) 45×; c) 90×. Reflected light.

In locating the boundaries of the zones the results of direct measurements and the assumption that the boundary of the crust with the screes S_1 (dehydrated brucite) corresponds to the solidification temperature of monticellite, i.e., 1490°C, and the boundary between the screes S_1 and the screes S_2 (raw brucite) to the temperature of the start of dehydration of brucite, i.e., 410°C were used. The convergence of the results obtained is high. The results of direct measurements showed that the radius of the fused portion of the block is determined bascially by the diameter of decomposition of the electrodes and the rate of fusion.

The diameter of decomposition of the electrodes in conducting the tests was constant (1100 mm) and determined in [1] as the optimum. The thickness of the unfused portion of the block, consisting of the crust and the screes S_1 and S_2, varies significantly and depends upon the diameter of the furnace shell and the radius of the fused portion of the block (Table 1).

The greatest radius of the fused portion of the block and the greatest thickness of the thermally insulating unfused portion, reaching 980 mm in the zone between the electrodes, is obtained with a comparatively high vertical rate of fusion of the block in a furnace with a large-diameter shell (first series of heats) (Table 1). The greatest heat liberation is observed in the zone of arcing, but as the result of the closeness of the electrodes to the heat-liberating surface of the normal shell in the form of a truncated cone the amount of accumulation of heat by the charge in the zone opposite the electrode is always smaller than in the interelectrode zone.

The same rule is followed for the heat consumed in dehydration of brucite. The sintered crust in the interelectrode zone is always thicker than in the zone opposite the electrode. The significant thickness of the unfused portion, especially in the interelectrode portion, causes excessive thermal insulation of the molten material, small temperature gradients, and weak liberation of heat through the solid phase, as the result of which the thermal conditions for columnar crystallization are not created.

Columnar crystallization is determined by the presence above all else of the temperature gradient in the solid phase and on the boundary of it with the liquid phase. The possibility of creation of a temperature gradient by overheating of the molten material is limited in view of the closeness of the melting point of periclase (2800 ± 13°C) to its boiling point (3005°C) [2]. Therefore, the amount of the temperature gradient is determined primarily by the intensity of heat liberation through the solid phase. At first the accumulation of heat by the charge and the consumptions of heat for its dehydration cause significant liberation of heat and maintenance of the necessary temperature gradient for columnar crystallization of the molten MgO.

With heating of the charge the heat liberation from the boundary of the phases decreases and the conditions for columnar crystallization are disturbed. With a decrease in shell diameter and average fusion rate, for example, by alternation of a high rate (40 mm/h) with a low rate (15 mm/h) [3] or by a periodic reduction in the nominal current [4], the thermal conditions are created for columnar crystallization (Fig. 4) as the result of the intensity of heat liberation through the solid phase, liberation of the heat of crystallization during fusion of the block, and supercooling in the thin layer of molten material at the boundary with the crystal. Crystallization of 1 mole of MgO is accompanied by liberation of 77 kJ of heat. The liberation of heat through the solid phase increases even more in melting the brucite in a furnace with a 2500-mm-diam. water-cooled shell. The temperature gradient per unit of thickness ($\Delta T/L$) of crystallized fused molten perclase, crust, and screes increases. At the same time, there is an increase in the thermal transmission transfer of molten silicates along the boundaries and channel voids of the hardened portion of the molten periclase, of that crystallized by the first, and of the crust to a depth to the isotherm of crystallization of monticellite.

The three-dimensional flow of molten silicates q (in cm^3/sec) and its rate of movement are in this case proportional to the motive force $\Delta T/L$ [5]: $q = kS(\Delta T/L)$, where k is the coefficient of transmission, in cm/sec; and S is the capillary cross-sectional area, in cm^2.

The crystallization pressure also influences the redistribution of the impurities and the structure of the periclase.

With heating and dehydration of the charge and distance of the front of crystallization from the furnace shell to the vertical axis of the furnace, there is an increase in the thermal insulation layer of the solid phase and a reduction in the intensity of heat liberation in it, and in charging the next portion of charge and raising of the electrodes, supercooling of a significant volume of the molten material occurs. In it a multitude of centers of crystallization of MgO occurs and they crystallize into the polycrystalline structure of periclase (Fig. 4b), enveloping a portion of the impurities, particularly of silicates. For the splashes and ejections of molten material from the furnace, which are subjected to rapid cooling, the formation of fine crystals of dendritic form is characteristic, and the silicate impurities are enveloped in growth of the branches.

A decrease in the thickness of the unfused charge and distribution in its layers of special crystallization agents and also the maximum possible heating of the molten material promotes intense heat liberation into the solid phase and a sharp reduction in the thickness of the supercooled zone and increases the time of stay of the tip of the crystal in the supercooled molten material. Under such conditions there is an increase in the rate of growth of the crystals and the possibility of origin of new individual crystals is eliminated [5].

The greatest effect on periclase quality and the technical and economic indices is obtained in melting brucite in a furnace with a water-cooled shell and a bath with the minimum optimum diameter of 2500 mm. Then $d_s = d_{de} + d_e/2 + (a + a_1)$ (Fig. 2), $d_{de} = 2.6d_e$, and $d_e = 400$ mm.

In melting in a furnace with the shell of the bath in the form of a truncated cone the total thickness of the crust and the screes in the interelectrode zone is 200-300 mm thicker than in the zone opposite the electrode. Therefore, in the interelectrode zone there are created less favorable thermal conditions for columnar crystallization than in the zone opposite the electrode, especially along the generatrix of the electrode facing the furnace shell. This is confirmed by the more developed zone of columnar crystals (single crystals) along the generatrix of the electrode than in the interelectrode zone.

In addition, in this case the greater thickness and weight of the unfused zone of the block, especially in the interelectrode zone, causes high specific consumptions of raw material and power and a larger volume of manual and loading and unloading work at the furnace. For the purpose of improving the conditions of columnar crystallization in the interelectrode zone and reducing the specific consumption of raw material and power by decreasing the weight of the unfused portion of the block, the shell of the bath is made in the form of a truncated triangular pyramid, the side edges of which are rounded on arcs coinciding with the equipotential lines encircling the electrodes and the ratio of the radius of curvature of the side edges to the diameter of the electrodes is 1.4-2.2 and to the diameter of decomposition of the electrodes 0.5-1.6 [6]. In replacement of the normal shell of a bath in the form of a truncated cone with a shell in the form of a truncated triangular pyramid there is a decrease in the specific consumption of raw material and power by 0.8-1.2 tons/ton and 530-870 kWh/ton, and a significant reduction in the volume of manual and loading and unloading work and the thermal conditions are created for columnar crystallization in the interelectrode zone.

CONCLUSIONS

Certain rules of columnar crystallization of periclase and of formation of the block in melting of brucite in an OKB-955N smelting furnace are considered.

Technological means of increasing the quality and technical and economic indices of production of fused periclase using the block method are proposed.

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