TESTING REFRACTORIES CONTAINING MAGNESITE – CHROMITE CLINKER IN THE ROOFS OF OPEN-HEARTH FURNACES

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Using the technology developed by the Dnepropetrov Metallurgical Institute together with the Magnezit and Zaporozhe Refractories Plants, an industrial batch of roof refractories weighing 1100 tons was prepared, using clinker obtained from caustic magnesite.

The clinker was prepared at the Magnezit Factory by the dry method [2] from 20-25% chromite and 75-80% caustic magnesite with contained 2-3% more magnesium oxide than the magnesite powder used for producing PShSO products. In addition the caustic magnesite was more homogeneous in its composition. The properties of the materials for producing the articles are given in Table 1.

The composition of the batch was 35-40% clinker fractions 3-1 mm, 30-25% clinker fractions 1-0 mm, 35% finely milled mixture based on 60% chromite and 40% magnesite (not less than 90% fractions <0.06 mm).

The preparation of the bodies, pressing, and drying of the goods was done with the cycles used at the Zaporozhe Plant. The products were fired in a tunnel kiln at a maximum temperature of 1700-1730°C with a soak of 4 h. The bricks were 460 mm and 520 mm long.

TABLE 1. Chemical Composition of the Starting Materials, %

Material	MgO	Cr_2O_3	SiO_2	Al_2O_3	CaO	Fe_2O_3
Magnesite – chromite clinker (average porosity 12%)	76,1	11,2	2,8	2,5	2,3	6,0
Magnesite – chromite powder	90,25	—	2,76	0,53	2,74	2,63
Chromite ore	23,25	48,25	5,15	6,32	0,96	12,3

TABLE 2. Properties of the Brick

Roof brick	Refractoriness under load, 2 kg/cm², °C	Spalling resistance (from 1300°C), heat cycles	Porosity, %	Compressive strength, kg/cm²	Chemical composition, %					
					MgO	Cr_2O_3	SiO_2	CaO	Al_2O_3	Fe_2O_3
Experimental	1618	5	15,6	550	66,7	17,3	3,94	2,40	3,94	5,74
Ordinary periclase – spinel	1565	6	16,5	464	74,05	11,68	4,82	2,25	Not determined	5,43

Dnepropetrovsk Metallurgical Institute. Zaporozhe Refractories Plant. Zaporozhe Steel Factory. Gisogneupor. Ministry of Ferrous Metallurgy of the Ukrainian SSR. Translated from Ogneupory, No. 5, pp. 23-27, May, 1971.

TABLE 3. Working Factors of the Open-Hearth Furnaces in Comparable Periods

Furnace No.	Start and termination of campaign	Production technology for the brick	Number of heats in the campaign	Average weight of the heat, ton	Average duration of the heats, h	Weight of steel melted during the campaign, ton	Consumption of oxygen, m^3/ton			Average intensity of oxygen feed, m^3/h	
							in the flame	in the tank on the quantity of blown heats	total	to the flame	to the tank
4	Sept. 13, 1966-Dec. 17, 1966	PShSO	303	239,5	7,15	72 215	41,6	12.8	48,1	1655	—
	Dec. 22, 1966-Mar. 12, 1966	PShSO	244	241,0	7,50	58 971	53,0	13,7	55,3	1880	1660
	Mar. 19, 1967-Nov. 29, 1967	PShSO	204* (332)	242,0	6,91	80 174	35,1	13,3	46,9	1800	1620
	July 5, 1967-Oct. 10, 1967	Clinker	288	242,3	7,27	69 809	52,9	24,8	57,3	1960	2270
6	Oct. 1, 1966-Jan. 15, 1967	PShSO	243	483,9	10,02	117 600	41,9	14,1	56,0	2370	2295
	Jan. 20, 1967-Apr. 27, 1967	PShSO	228	482,4	9,89	109 991	39,5	12,7	52,2	2315	2085
	May 2, 1967-July 24, 1967	PShSO	197	486,0	10,01	95 742	44,1	13,6	57,6	2520	2145
	July 29, 1967-Nov. 15, 1967	Clinker	244	481,8	10,21	117 566	37,5	16,9	54,4	2450	2385
7	July 22, 1966-Oct. 21, 1966	PShSO	203	480,0	10,32	97 665	42,7	10,81	53,5	2420	—
	Oct. 29, 1966-Feb. 14, 1967	PShSO	265	485,0	9,60	127 273	38,7	9,5	46,7	2000	—
	Feb. 18, 1967-July 15, 1967	PShSO	183† (335)	481,0	10,11	87 928	40,6	11,9	52,2	2340	2290
	July 25, 1967-Nov. 23, 1967	Clinker	197‡ (290)	481,5	9,66	94 882	35,9	11,7	46,7	2390	2459
11	June 7, 1966-Nov. 4, 1966	PShSO	335	482,5	10,34	161 684	44,7	10,5	54,6	2335	—
	Nov. 7, 1966-Feb. 4, 1967	PShSO	206	474,6	10,20	97 790	43,0	11,3	54,0	2270	—
	Feb. 10, 1967-June 24, 1967	PShSO	157** (295)	481,6	10,53	142 069	40,0	11,3	51,2	2260	2230
	July 2, 1967-Oct. 30, 1967	Clinker	272	475,4	10,30	129 327	41,5	9,8	51,5	2325	2065

* Notation near the asterisks indicates figures before stoppage for cold repairs, in parenthesis the total campaign time.

† The central part of the roof was completely replaced.

‡ 37 Rings of the central part of the roof were replaced.

** The same for 59 rings.

TABLE 4. Wear of Experimental and Ordinary Periclase–Spinel Roof Brick for Three Furnace Campaigns

Intensity of wear per heat, mm	Furnace No.5				Furnace No.6				Furnace No.7				Furnace No.11			
	PShSO			experimental	PShSO			experimental	PShSO			experimental	PShSO			experimental
	1	2	3		1	2	3		1	2	3		1	2	3	
Average	1,04	1,35	1,50	1,0	1,09	1,10	1,5	1,0	1,4	1,03	1,50	1,1	0,97	1,1	1,4	1,0
Maximum	1,20	1,50	1,75	1,5	1,27	1,50	1,8	1,3	1,6	1,30	2,08	1,2	1,07	1,3	1,9	1,2
Minimum	0,92	1,20	1,37	0,8	0,86	0,35	1,0	0,6	1,3	0,80	0,90	1,0	0,83	0,9	1,0	0,7

TABLE 5. Results of Investigations of the Brick after Service

Production technology	Brick zone	Thickness of zone, mm	Chemical composition of zone, %					
			MgO	Cr_2O_3	SiO_2	CaO	Al_2O_3	Fe_2O_3 +FeO
Clinker	Working	6—10	38,3	17,8	3,92	4,69	5,72	29,6
	Sintered	8—12	61,7	16,7	4,94	5,31	3,90	7,41
	Least changed	2—6	66,7	16,7	4,20	2,20	3,54	7,0
Periclase – spinel	Working	15—30	49,86	9,84	3,50	6,50	3,7	36,30
	Sintered	30—60	69,9	8,88	5,60	7,78	3,7	4,20
	Periclase – spinel	20—25	76,3	10,7	4,05	1,45	3,05	4,35

The properties of the experimental roof refractories made by using clinker and also periclase–spinel refractories produced by the Zaporozhe Plant are given in Table 2. The clinker products have the better properties.

Service of Roof Refractories in Open Hearth Furnaces. The experimental brick was used to make the roofs of four open-hearth furnaces at the Zaporozhe Steel Factory: furnace No. 4 with a burden of 250 tons, and furnaces Nos. 6, 7, and 11 with burdens of 500 tons. The roofs of the furnaces were of the thrust-suspension type with a ribbed construction with suspensions of the Ukrainian Institute system. The furnaces were operated by the scrap-ore process using about 60% liquid iron in the batch. The oxygen was fed into the flame and through the roof lances into the bath.

During the operation of the open-hearth furnaces with the experimental roofs certain technical features were noted in each of them.

Furnace No. 4. During the campaign with the experimental roof, the intensity of feeding oxygen into the bath was 50% greater than usual, the last 49 heats of the campaign were blown with oxygen feed of 3470 m^3/h, which in terms of intensification of steel melting approximated to the working cycle of furnace No. 5. The time of the heat was greatly reduced and equaled 5.99 h. Usually the duration of the heat without blowing oxygen in the tank is 7.74 h.

Furnace No. 6. After 194 heats was stopped in connection with the emergency demolition of the "joint" from the surface of the right vertical channel. After the second breakout it was stopped for cold repairs although the state of the main roof permitted continuation of the campaign.

Furnace No. 7. Subjected to guncreting with magnesite–chromite body; the roof of the experimental brick was worn by scaling, and after 197 heats it was necessary to replace 37 rings of the central zone.

The working factors for the operation of the furnaces in the comparable periods are given in Table 3. After completion of the campaign during cold repairs measurements were made of the residual thickness of the roof, and the wear intensity of the refractories determined in millimeters per heat. Comparative results for the wear per heat of the experimental clinker refractory and the periclase–spinel refractory in terms of the campaigns for each furnace are given in Table 4.

On average for the entire experimental roof system the wear per heat of refractories using clinker is 25% less than that of periclase–spinel refractories for the three previous campaigns.

Investigation of Refractories after Service. In the worked roof brick both the experimental, using clinker, and the usual pericalse–spinel composition, measurements were made of the thickness of the zones, and samples taken from each zone for petrographic and chemical–mineralogical study (Table 5).

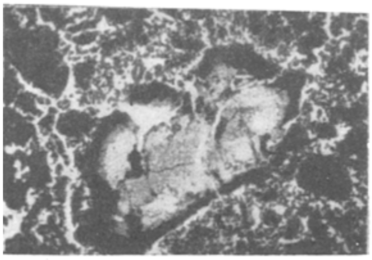

Fig. 1

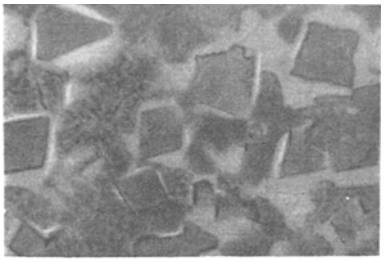

Fig. 2

Fig. 1. Microstructure of periclase–spinel refractory. Without analyzer (×32). Transmitted light.

Fig. 2. Microstructure of clinker refractory. Without analyzer (×160). Transmitted light.

Under the action of slags and dust at elevated temperatures the brick acquired a zoned structure which is due to the movement through its capillaries of more fusible silicate compounds toward the cooler side of the roof brick.

Petrographic studies showed that the periclase–spinel refractories are not homogeneous in structure. Besides the complex spinel Mg $(Fe, Al, Cr)_2O_4$, they contain coarse grains of periclase measuring from 0.5 to 4 mm in amounts of 30-40% of the whole area of the slide (Fig. 1).

The monticellite formed in the refractory and other silicates in the form of fusible phases penetrate into the slag. The pores are mainly longitudinal channel types, contributing to movement of liquid phases.

During firing both in the clinker and in the experimental roof refractories the chromite and magnesite incorporated in the batches after combined grinding (finer than 60 μ) undergo reactions, with the formation of more uniformly distributed complex spinel Mg $(Al, Fe, Cr)_2O_4$ (rhombic, triagonal, and irregular crystals in Fig. 2).*

The remaining part of the periclase which is not present in the complex spinel, is uniformly distributed between the complex spinel in the form of fine grains of oval shape impregnated by very fine crystals of complex spinel.

The forsterite, monticellite, and possibly other fusible compounds are distributed in the form of very fine films between the complex spinel and the periclase. The pores are fine and rounded in form.

CONCLUSIONS

Roof refractories made using magnesite–chromite clinker obtained from caustic magnesite in the comparative tests had better factors, and a more homogeneous structure than periclase–spinel, and ordinary magnesite–chromite roof refractories. The wear resistance of the roof refractories (in millimeters per heat) made by the proposed technology, using clinker, is 25% higher in average experimental campaigns compared with the three previous campaigns.

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* The surrounding crystals of spinel in the body of the refractory apparently were partly broken up during preparation of the thin section.