of the nozzle channels is appreciably reduced, because apparently in this case the only process which can still occur is precipitation of the nonmetallic phase.

Our analysis confirms that to eliminate or reduce overgrowth and erosion of the batcher channels of pouring equipment, it is necessary to create refractory materials which interact weakly or not at all with the nonmetallic phase of the steel. Other ways of avoiding overgrowth of the channels might include finding refractory materials which form a liquid phase, which promotes wetting of the inclusions by the stream of metal, at the contact boundary with refractory nonmetallic inclusions in the steel. However, this method is limited by possible increase in the diameter of the channel during pouring.

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SERVICE OF MULLITE—SILICEOUS JACKETS OF HIGHER QUALITY IN COWPER STOVES

N. V. Semkina and N. I. Solov'ev

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Despite the development of contactless methods of temperature monitoring in blast furnaces [1, 2], the temperature of the gaseous medium in cowper stoves is measured by standard TPP-2 and TPG-0555 thermocouples with PR 30/6 platinum—rhodium thermoelectrodes in protective jackets of corundum [3], fused quartz [4], or silicon carbide (GOST 10153-70).

Hitherto the maximum durability (up to 6 months) has been exhibited by fused quartz jackets made by the Gusev Glass Works [4]. However, as a result of the intensification of blast-furnace operation the temperature of the gaseous medium in cowper stoves has been elevated. At the Magnitogorsk Metallurgical Combine (MMC) it reaches, e.g., 1450-1470°C and continually fluctuates in the range 800-(1430-1470)-800°C during switching of the channels; the gas pressure in the cowper stoves is about 0.30-0.35 MPa. At these high temperatures fused quartz jackets become soft; thermoelectrodes fail in 3-4 days.

Mullite—siliceous long (1500-2000 mm) jackets of enhanced quality with added commercial zirconium dioxide (50-52% Al_2O_3, 38-39% SiO_2, and 3-4% ZrO_2 [5]) have been proposed for service under more complex conditions. Since 1979 commercial zirconium dioxide has been replaced by a more plentiful material — baddeleyite of PB-1 grade (TU 14-8-208-74); this has not led to any change in the procedure for making the jackets. Artifacts with added baddeleyite, made* at the Podolsk Refractory Artifacts Works, met the requirements of TU 14-8-116-74 and had a lower water absorption (0.1-0.15%) and a higher heat resistance (not less than five heating—cooling cycles in air from 1200°C) than mullite—siliceous tubes. Table 1 gives the results of their use in cowper stoves of the MMC.

The mean durability of the jackets is in the range 85-104 days, the reliability is 92%; 8% of the artifacts fail in the first 5-10 days as a result of shear of the cowper-stove lining. After service at relatively low temperatures (up to 1350°C) the artifacts are unaltered. Their surface has a deposit of dust containing, e.g., 30% Al_2O_3, 39% SiO_2, 18% Fe_2O_3, 10% MgO, and 2% CaO. Some of the dust components penetrate 5-7% of the artifact thickness via microcracks, leading to spallation of the working part of the jacket.

*Under the direction of S. E. Yurin and M. I. Shcherbakova.

Eastern Institute of Refractories. V. I. Lenin Magnitogorsk Metallurgical Combine.

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TABLE 1. Results of Tests of Jackets*

Furnace No.	No. of tested artifacts	Service conditions		Mean service life, days
		pressure of gas, MPa	gas temp., °C	
1	6	0,22	1350	104
2	6	0,27	1350	101
3	5	0,28	1350—1430	91
4	5	0,31	1350—1430	85
5	4	0,22	1400—1430	86
6	4	0,22	1320—1470	89
7	5	0,32	1400—1450	87
8	4	0,25	1420—1470	85
9	5	0,32	1320—1450	81
10	5	0,35	1350—1470	96

*After service in furnaces Nos. 1-5 the jackets were unaltered; a brown deposit was observed on the surface; in furnaces Nos. 6-10 the working sector of the jackets was elongated.

At higher service temperatures (up to 1470°C) penetration of dust is not observed, the working sector of the jacket (150-200 mm) is deformed and elongated; during deformation of the jacket, fracture of the thermoelectrode is observed. The high reliability of the jackets during prolonged operation and with a constant temperature drop (from 20 to 1470°C) along their length is due to the resistance of the material to thermal stresses as a result of the incorporation of zirconium dioxide.

The monoclinic zirconium dioxide is present in the free state, reducing the stresses during heating and temperature drop. During service zirconium dioxide remains in the free state only in the relatively cold part of the jacket (up to 1200-1350°C) for one-third of the length from the open end. In the lower working sector of the jacket, after service for 90 days zirconium dioxide is no longer present in the free state, because it is gradually passed into the glass after 60 days. In this connection the material of the jacket is a recrystallized intergrowth of small mullite grains in the form of needles measuring 0.005 mm and glass.

Corundum, present in the material as grains (10%), also dissolves in the glass during service; only isolated corundum grains are observed. At the contact with the dust, iron oxides penetrate into the base material with formation of ferriferous glass. In the dust itself we observe ferriferous spinel, calcium aluminates, and, as shown by local spectral analysis, forsterite.

The results of the investigations of artifacts after service provide an explanation of the high durability of mullite—siliceous jackets with added zirconium dioxide (baddeleyite), as follows; during prolonged service, in the working sector of the artifact zirconium dioxide and aluminum oxide dissolve in the liquid phase and thus increase its deformability and chemical resistance to the action of the components of the ferriferous dust. The pyroplastic state of the high-refractory materials protects the artifact against penetration of high thermal stresses. Jackets of mullite—siliceous composition without added zirconium dioxide [5] had a durability of only 30 days under these conditions and they failed as a result of the low resistance to sudden heatings and a constant temperature drop along the length of the artifact.

Thus, the durability of mullite—siliceous jackets in cowper stoves with elevated temperatures of the gaseous medium (up to 1430-1470°C) is determined by the resistance of the material to sudden heatings and a constant temperature drop (20-1470°C) and the resistance to the action of ferriferous dust deposited on the surface of the working sector of the jackets. On the average, the durability of jackets with added baddeleyite is 90 days.

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