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INCREASING THE ENDURANCE OF ELECTRODES OF HEATING SALT TANKS

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Electrodes used for heating, melting, and sustaining the requisite temperature regime in salt tanks for heat treatment of metals and alloys operate under severe conditions (heating to 1300°C, aggressive medium of the melts of salts of alkali and alkali-earth metals). This causes early failure of the electrodes, and the heat treatment unit is stopped for repair. For example, the design service life of electrodes for SVS 2.3/13I tanks is two months, but as a rule it does not exceed one month of continuous operation. The replacement of conventional low-carbon electrode steel (for example, of grade 10) by a more expensive heat- and corrosion-resistant steel has not proved effective but rather increased the cost of the electrodes and hence the cost of the produced parts. In this connection, it is interesting to get acquainted with works devoted to increasing the service life of salt-tank electrodes for heat treatment shops of machine-building and tool plants. The present paper describes such an attempt.

In order to increase the endurance of electrodes it is recommended to place them in outer nozzles made of a refractory material that conducts electricity and is chemically inert to the salt melts used. The most expedient material for the purpose is siliconized graphite, which is produced by domestic industry and is quite suitable for the production of such nozzles.

The siliconized graphite is based on silicon carbide. Electrodes with nozzles of such a material will have a high chemical resistance to reactions with salts of alkali and alkali-earth metals. Table 1 presents the data of [1, 2] on the chemical resistance of siliconized graphite to various melts used in salt tanks for heat treatment of metals and alloys.

It can be seen that nozzles of siliconized graphite not only possess a high heat resistance but are chemically stable in salt melts used in industrial heat treatment of metals and alloys.

TABLE 1

Chemical compound	t_m, °C	t_{int}, °C
KOH	318	900
NaCl	800	–
Na_2CO_3	851	900
Na_2CO_3+ K_2CO_3 (1 : 3)	–	1000
K_2CO_3	891	1000
Na_2O_2	–	500
K_2CO_3+ KNO_3 (1 : 2)	–	500
M_2Cl_2	718	1000
KCl	720	–
$CaCl_2$	772	–
$BaCl_2$	900	–

Notation: t_m is the melting temperature, t_{int} is the temperature of the interaction with SiC.

In addition to chemical resistance the nozzles are characterized by electrical resistivity (ρ), thermal conductivity (λ),

TABLE 2

t, °C	$\rho \times 10^3$, $\Omega \cdot m$	t, °C	$\rho \times 10^3$, $\Omega \cdot m$	t, °C	$\rho \times 10^3$, $\Omega \cdot m$
Siliconized graphite SG-M					
400	11 – 14.2	700	9.9 – 11.9	1000	9.6 – 11.1
500	10.5 – 13.2	800	9.7 – 11.5	1500	10.8 – 11.1
600	10.1 – 12.4	900	9.6 – 11.1	2000	11.5 – 12.2
Siliconized graphite SG-T					
400	42 – 50	700	33.5 – 38.5	1000	28.5 – 35
500	38 – 45	800	31.5 – 35.5	1500	27.5 – 35
600	36 – 38.5	900	30 – 35.5	–	–

TABLE 3

t, °C	λ, W/(m · K)	t, °C	λ, W/(m · K)
Siliconized graphite SG-M			
100	75 – 110	600	92 – 115
150	125 – 170	700	82 – 96
200	150 – 203	800	75 – 83
250	162 – 209	900	69 – 74
300	162 – 192	1000	65
400	120 – 160	1500	43
500	105 – 135	2000	31
Siliconized graphite SG-T			
100	150	600	93
150	260	700	83
200	250	800	75
250	210	900	67
300	170	1000	60
400	125	1500	38
500	108	–	–

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and wettability. Tables 2 and 3 [3, 4] present these characteristics for siliconized graphi-te of grades SG-T (60 – 75% SiC, 12 – 20% Si, 28 – 5% C) and SG-M (32 – 45% SiC, 5 – 9% Si, 63 – 46% C).

Table 4 presents the characteristics of the strength, hardness, thermal conductivity, and thermal expansion of siliconized graphite. It should be noted that siliconized graphite is poorly wettable by salt melts, which makes it possible to replace the nozzles during operation of the tank. The use of nozzles of siliconized graphite makes it possible to produce electrodes from inexpensive low-carbon steels. Siliconized graphite is manufactured by silicon impregnation of graphite parts. Siliconized graphite is characterized by the presence of soft graphite in addition to a solid carbide phase. Silicon carbide makes the siliconized graphite more heat- and corrosion-resistant, and the graphite acquires a high-temperature strength and antifriction properties. The industry produces various parts of siliconized graphite, for example, sealing rings for pumps and immersion electric motors for pumping aggressive and erosive liquids, facing cylinders and spinning disks for cord machines for the production of artificial fibers, and press molds resistant to the action of molten glass.

However, the material has not yet found application in the heat treatment of metals and alloys in liquid media, though parts of siliconized graphite possess a high resistance to the effect of the appropriate salt melts. The technology for manufacturing the nozzles consists of two operations, i.e., turning them from preforms of graphite of grades PG-50 and PROG-2400 in correspondence with the size of the electrodes and impregnating the turned preforms with molten silicon (for example of grade Kr0) in a high-temperature furnace at 1900°C with subsequent carbidizing. Nozzles manufactured by this method are ground (if necessary), put on the metallic electrodes (Fig. 1), and placed into the salt tank for operation.

TABLE 4

Graphite	σ_r, N/mm^2	σ_b, N/mm^2	σ_c, N/mm^2	*HRC*	λ, W/(m · K) at a temperature of, °C		$\alpha \times 10^6$, K^{-1} at 100°C
					100	500	
SG-T	400 – 500	900 – 1100	1000 – 3200	65 – 78	98.6	63.8	3.5
SG-M	300 – 400	700 – 900	1300 – 1600	40 – 56	139.2	104.4	4.5

Notation: σ_r, σ_b, and σ_c are the rupture, bending and compressive strengths respectively; λ is the thermal conductivity, α is the coefficient of thermal expansion.

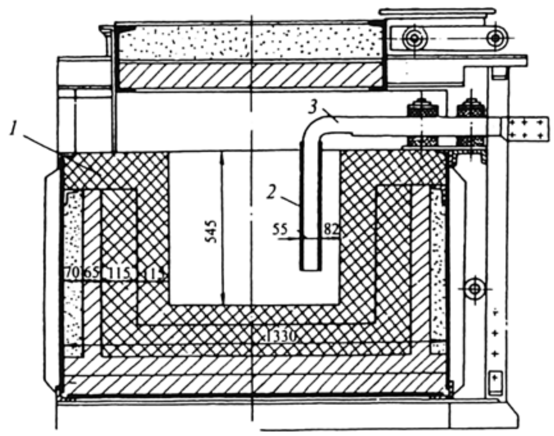

Fig. 1. Position of electrodes with nozzles in a salt tank: *1*) salt tank, *2*) nozzle; *3*) electrode.

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