

THE DISSOLUTION KINETICS OF REFRACTORIES IN GLASS MELT

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The paper deals with the corrosion rate of refractories in glass melt under isothermic conditions. On the basis of theoretical analysis, experimental results and critical evaluation of published corrosion rates the authors have suggested more accurate forms of equations for the calculation of flow corrosion and of that at glass melt level in terms of glass melt viscosity and other conditions. The equations can be used with satisfactory accuracy also in the corrosion of operational, multi-component refractories in technical glass melts.

INTRODUCTION

Corrosion of refractories limits the life of melting furnaces, the melting temperature and thus also the furnace throughput, thus seriously affecting the furnace economy. However, so far there have been available very limited numbers of rules and data which would allow to calculate reliably the corrosion rate in relation to operational conditions. The known equations have been derived on model materials, on the basis of dissolution of monocrystals in various glass melts, or only theoretically [3], [5], [6], [7], [9], [10].

Dissolution of operational refractories in technical glass melts is governed by considerably more complex conditions, the description of which has to be suitably simplified so as to make them practically applicable. For this reason the corrosion process has been studied under isothermic conditions and on fresh samples whereas in actual operation both temperature and composition of the surface layer of the corroded refractory are subject to variations, temperature gradients arise both in the refractory and in the melt, and the course of corrosion is affected by inhomogeneities in the refractory material.

THE CORROSION RELATIONSHIPS

Corrosion of a refractory in glass melt is a special case of dissolution of a solid in a high-viscosity melt. The process is usually controlled by diffusion [1], [4], [5]. It is possible to distinguish several types of corrosion differing in the mechanism causing the movement of melt along the phase boundary:

For the case when the glass melt flow is due to an external effect, e.g. in mixing, flow through a channel and in particular for the laboratory dynamic corrosion test the following equation has been derived [1], [2], [3], [5]:

$$W_g = 0.33 \frac{D^{2/3} u^{1/2}}{x^{1/2} \cdot \nu^{1/6}} \Delta c. \quad (1)$$

Density flow along a vertical wall is described by the equation derived by a number of authors, [1], [2], [3], [6], [7]:

$$W_g = 0.51 \frac{D^{3/4} \Delta c^{1/4} g^{1/4}}{x^{1/4} \nu^{1/4}} \Delta c. \quad (2)$$

The value of the constant is given by [1], [2] between 0.49 and 0.54. Hrma has derived the following equations for the corrosion rate at the point of contact of three phases where the flow is due to surface tension forces [6], [7], [9], [10]:

$$W_g = 0,43 \frac{D^{2/3} \Delta \sigma^{1/3} g^{1/3}}{\nu^{1/3}} \Delta c. \quad (3)$$

Since diffusion is the controlling process of corrosion in all instances, there holds the Noyes-Nernst equation [1] adjusted to linear corrosion rate:

$$w_l = \frac{D}{\sigma_{ef} \rho_z} \Delta c \quad (4)$$

The boundary layer thickness δ_{ef} is generally a function of similarity criteria [1]:

$$\delta_{ef} = \frac{x}{K} Sc^{-m} M^{-n} \quad (5)$$

which is only a special form of the general equation for heat and mass transmission:

$$Sh = K \cdot Sc^m \cdot M^n \quad (6)$$

where Sh is the Sherwood criterion, $Sh = \frac{w_g \cdot x}{D \Delta c}$, Sc is the Schmidt criterion

$Sc = \frac{\nu}{D}$ and M is another criterion characterizing the movement of melt along the boundary. In the case of corrosion at forced flow there is the Reynolds criterion: $Re = \frac{xu}{\nu}$; in that of free convection the Grashoff criterion: $Gr = \frac{gx^3 \Delta \rho}{\nu^2}$. The rate of corrosion at the glass level depends on an analogous criterion expressing the effects of surface tension on the glass melt flow: $Hr = \frac{gx^3 \Delta \sigma}{\nu^2}$.

An analysis of equations (1), (2) yields $K = 0.33$, $m = 1/3$, $n = 1/2$ for flow corrosion, and $K = 0.51$, $m = 1/4$, $n = 1/4$ for free convection. The ratio of both the exponents and the constants corresponds to the theoretical relation between the criteria,

$$Gr = \frac{1}{4} Re^2. \quad (7)$$

According to equation (3), for corrosion at glass level $K = 0.43$, $m = 1/3$, $n = 1/3$, which corresponds to the equation for heat transmission during turbulent spontaneous convection. As follows from the analogy with heat transmission, different values of exponents m and n will hold for experiments carried out under different conditions.

EXPERIMENTAL RESULTS

The corrosion rate was measured on three electrofused refractories of corundum-baddeleyitic type, the characteristics of which are listed in Table I.

Table I
The refractories employed in the corrosion tests

Material	A	B	C
Mark	KLB	ER 1681	ER 1711
Composition Al_2O_3	54.8	50.7	45.8
ZrO_2	30.1	32.0	40.8
SiO_2	13.5	15.8	12.3
TiO_2	0.1	0.1	0.1
Fe_2O_3	0.1	0.1	0.1
$\text{CaO} + \text{MgO}$	0.5	0.2	0.1
$\text{Na}_2\text{O} + \text{K}_2\text{O}$	0.9	1.1	0.8
Density g/cm ³	3.84	3.82	4.13

The samples 18 mm in diameter were bored from one stone each; however, the effect of segregation and structural change in the casting cannot be ruled out entirely. The measurement was carried out in white sheet glass melt having the following composition: 72.5 % SiO_2 , 0.95 % Al_2O_3 , 0.05 % Fe_2O_3 , 8.20 % CaO , 3.90 % MgO , 13.85 % Na_2O , 0.30 % K_2O , 0.25 % SO_3 . The viscosity of the melt was measured and the results can be expressed by the FVT equation having the form

$$\log \eta = -0.898 + \frac{3\,443.7}{t - 330.2}$$

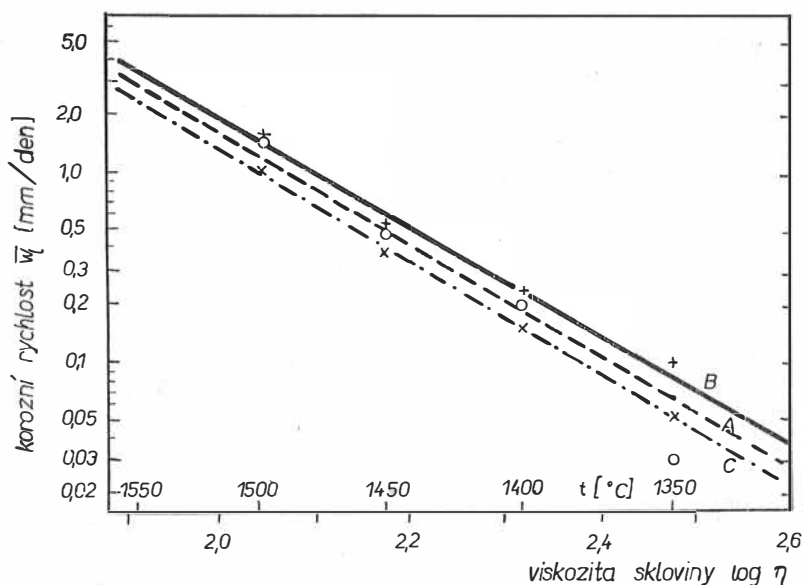


Fig. 1. The glass-level corrosion rate of refractories (mm/day) in white sheet glass melt vs. glass melt viscosity. The refractories are specified in Table I; O — refractory A; + — refractory B, × — refractory C.

The rate of corrosion was measured by the dynamic rod test. The samples to be measured were cemented into a holder and after the furnace had been heated up the samples were immersed in the glass melt in a crucible which was then put into rotary motion. After a chosen period of time the sense of rotation was reversed. After concluded test the samples were lifted from the crucible so as to allow the glass melt to drip off.

The glass level (flux line) corrosion was measured several times with a vernier calliper. The below-level corrosion was measured along a section 30 mm in length situated about 10 mm below the flux line using a mercury volumometer and the respective loss in volume was recalculated and expressed as mean linear corrosion. In the corrosion tests the corrosion rate was in the range of 1 to 45 mm per month which is on the whole comparable to the rate of corrosion under operation conditions.

The test period was chosen between 30 and 72 hours so as to attain measurable corrosion depths. The experiments were carried out at temperatures from 1350 to 1500 °C which correspond to glass melt viscosity of 110 to 300 dPa .s. The speed of the samples was varied between 2.5 and 8 r.p.m., that is between 0.8 and 2.5 cm/s.

The accuracy of the corrosion rate determination, which was estimated on the basis of analyses of parallel and repeated determinations, was found to depend markedly on the type (homogeneity) of the material. The highest accuracy was achieved with material B, the lowest with material A. The mean accuracy of one corrosion rate determination at the level amounts to ± 25 %, that below the level to ± 29 %.

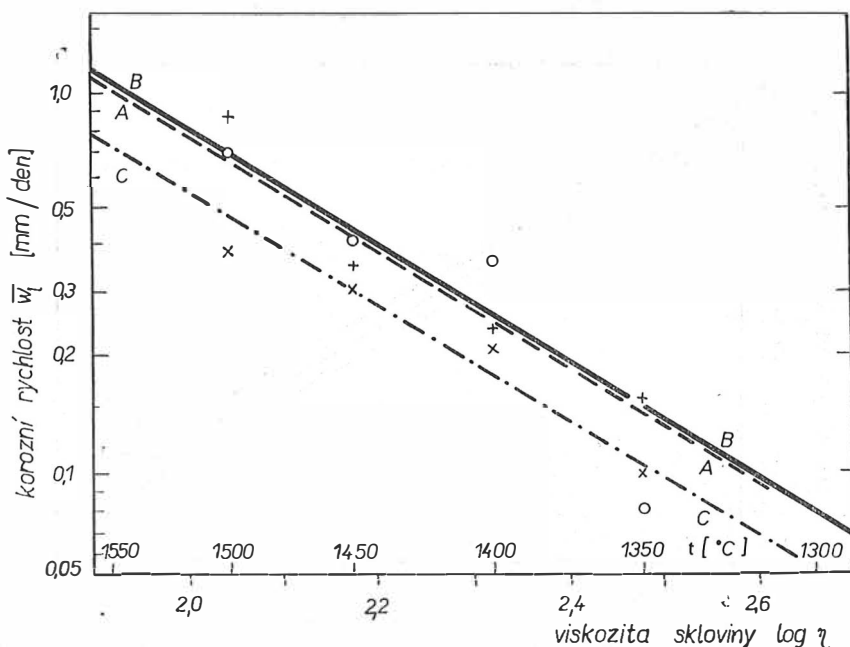


Fig. 2. The below-level corrosion rate of refractories (mm/day) in white sheet glass melt vs. glass melt viscosity. The measurement was carried out at a flow rate of 1.57 cm/s.

The results of the effect of viscosity on the corrosion rate, as plotted in Figs. 1 and 2, can be expressed by the equation

$$w_l = \frac{k}{\eta^s} \quad (8)$$

The values of constants k and s for the individual materials are listed in Tables II and III. The individual measurements comply with equation (8) with an accuracy of ± 5 to 40 %; at the level the mean accuracy is ± 20 % and below the level it amounts to ± 28 %. This dispersion corresponds to the inaccuracy of the actual corrosion rate measurement.

Table II
Evaluation of glass-level corrosion measurements

Material	Constants in eq. (8)		Accuracy $\pm$ %	Constants in eq. (17)	
	$g/cm^3 \cdot s^4$	s		$K_h \cdot C^{5/3} \cdot \Delta c \cdot \Delta \sigma^{1/3}$	$K_h \cdot C^{5/3} \cdot \Delta c$
A	2.30	3.02	40	0.26	0.41
B	2.47	2.96	15	0.28	0.44
C	1.54	2.98	5	0.19	0.30
Mean		2.99	20		

Table III
Evaluation of flow corrosion measurements

Material	Constants in eq. (8)		Accuracy $\pm$ %	Constants in eq. (15)	
	$g/cm^3 \cdot s^4$	s		$\frac{K_p \cdot C^{3/4} \cdot \Delta c \cdot \rho^{3/4}}{Qz}$	$K_p \cdot C^{3/4} \cdot \Delta c$
A	$8.50 \cdot 10^{-4}$	1.54	40	$5.39 \cdot 10^{-4}$	$1.04 \cdot 10^{-3}$
B	$8.80 \cdot 10^{-4}$	1.54	15	$5.56 \cdot 10^{-4}$	$1.07 \cdot 10^{-3}$
C	$6.22 \cdot 10^{-4}$	1.50	25	$3.94 \cdot 10^{-4}$	$0.82 \cdot 10^{-3}$
Mean		1.53	26		

The effect of glass melt movement on the rate of corrosion below the level is plotted in Fig. 3. The rate of below-level corrosion increases linearly with increasing glass melt flow rate. The rate of glass-level corrosion is at first not affected by the melt flow rate but at high melt flow rates the rate of this type of corrosion also increases.

AN ANALYSIS OF PUBLISHED CORROSION RATE MEASUREMENTS

Already McCallum and Barret [4] pointed out that in the case of slags the corrosion rate depends on their viscosity and that there is a linear relationship between $\log w$ and $1/T$; the same conclusions were reached by Hrma [7] and

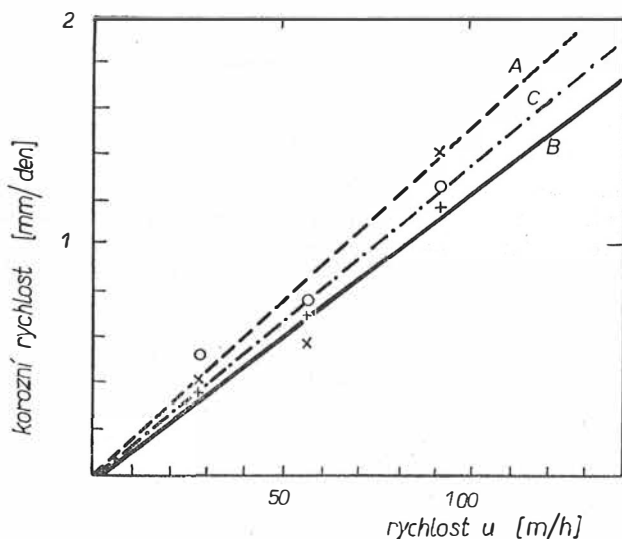


Fig. 3. The below-level corrosion rate of refractories (mm/day) vs. glass melt flow rate m/hour. Measured at 1500 °C, i.e. at a viscosity of 110 mPa.s.

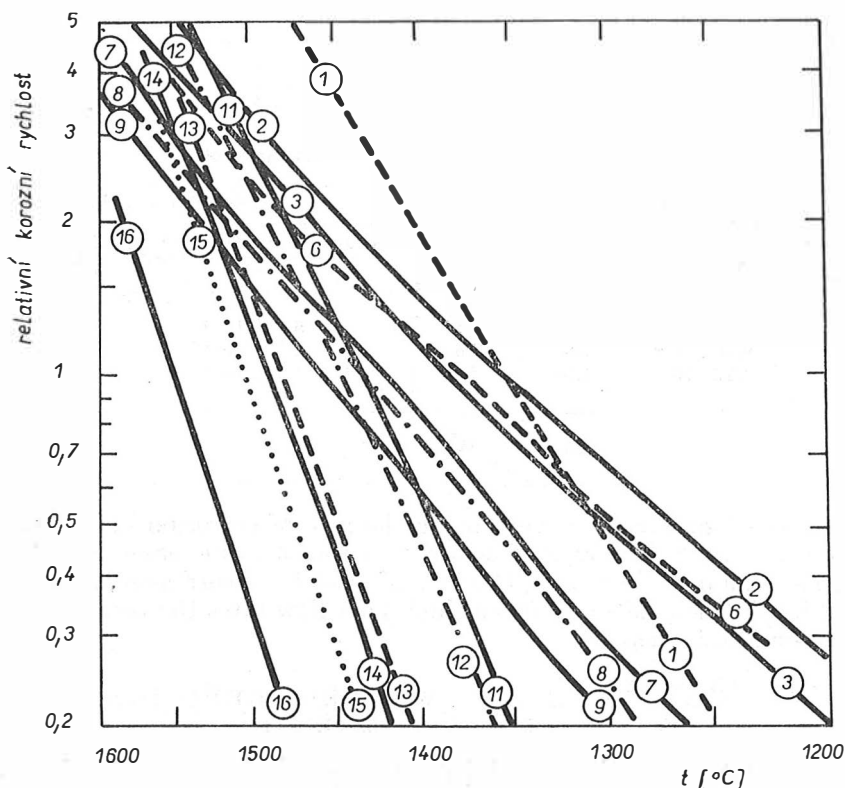


Fig. 4. The relative corrosion rates of various refractories in white glass melt vs. temperature according to data published by various authors. Explanatory notes to the curves are given in Table IV.

experimentally established for refractories by Lakatos and Simmingsköld [8].

For this reason the curves for temperature dependence of the corrosion rate published by various authors for various materials were transformed into $\log w$ vs. $1/T$ coordinates; the resulting relationships are virtually linear as shown in Fig. 4, and the dispersion is very small.

Curves 1 to 3, established by Daudans [13] for electrofused refractories, were determined in a small rotary tank furnace, i.e. in the case of flow corrosion. Only relative results are given. The curves found by Popov [14] for electrofused materials with various ZrO_2 contents are specified in absolute values and apply to sub-level flow corrosion. Curves 11 to 16 determined by Sleggs [15] for various electrofused materials hold for glasslevel corrosion. Table IV lists likewise some older results for fireclay and other similar materials, in all cases as relative values.

Table IV
Analysis of published corrosion relationships

Curve No.	Ref.	Material	Constants in eq. (10) for corrosion			Constants in eq. (8) for corrosion in cm/s		
			$P \cdot 10^{-3}$	K	$\pm \%$	s	k	k_{rel}
1	11	$\alpha - \beta - Al_2O_3$	14.48	8.96	2	1.76	1.41	25.85
2		32 % ZrO_2	11.95	7.31	9	1.46	$5.44 \cdot 10^{-2}$	1.00
3		41 % ZrO_2	11.81	7.13	7	1.44	$3.78 \cdot 10^{-2}$	0.70
4	12	Cast	12.03	7.65	4	1.47	$1.20 \cdot 10^{-1}$	
5	13	Fireclay	11.95	7.42	3	1.46	$5.63 \cdot 10^{-2}$	
6	14	33 % ZrO_2	12.19	8.33	8	1.49	$5.44 \cdot 10^{-1}$	1.00
7		41 % ZrO_2	12.19	8.19	4	1.49	$3.94 \cdot 10^{-1}$	0.72
8		45 % ZrO_2	12.19	8.13	3	1.49	$3.45 \cdot 10^{-1}$	0.63
9		50 % ZrO_2	12.11	8.01	5	1.48	$2.66 \cdot 10^{-1}$	0.12
10	16	Fireclay	12.25	7.58	8	1.49	$9.55 \cdot 10^{-2}$	
11	15	$\alpha - \beta - alumina$	25.93	16.50	5	3.16	$3.90 \cdot 10^6$	0.59
12		$\alpha - alumina$	25.81	16.37	4	3.14	$2.94 \cdot 10^6$	0.14
13		33 % ZrO_2	27.53	16.99	7	3.35	$6.57 \cdot 10^6$	1.00
14		36 % ZrO_2	27.53	16.83	3	3.35	$5.76 \cdot 10^6$	0.88
15		41 % ZrO_2	27.54	16.79	3	3.35	$5.25 \cdot 10^6$	0.80
16		$Cr_2O_3 - Al_2O_3$	27.53	16.37	3	3.35	$1.99 \cdot 10^6$	0.30

All the measurements made within the framework of the present study were carried out with white sheet-type glass melt. The curves for the corundum-baddeleyitic materials as well as those for fireclay exhibit a fairly regular course, those for corundum materials show a somewhat irregular course of the relationship.

The glass melt viscosity can be approximately expressed by the equation

$$\log \eta = A + \frac{B}{T} \quad (9)$$

For the current type of white sheet glass melt the average values of the constants are $A = -0.79$ and $B = 8210$.

All the published corrosion curves can be described with a satisfactory accuracy ($\pm 5\%$) by the equation

$$\log w_l = K - \frac{P}{T}. \quad (10)$$

By combining equations (9) and (10) one obtains the dependence of corrosion rate on glass melt viscosity:

$$\log w_l = K + \frac{PA}{B} - \frac{P}{B} \cdot \log \eta \quad (11)$$

which is identical with equation (8). Here, $\log k = K + \frac{PA}{B}$ and $s = \frac{P}{B}$.

For the relationships being analyzed, the values of the constants are listed in Table IV.

DISCUSSION

The exponent s in equation (8) for the effect of viscosity on corrosion rate is constant for measurements of the same type. In the case of glass-level corrosion measurements specified in Table II it was found that $s = 2.99 \pm 0.02$; an analysis of the Sleggs' measurements (15) yields $s = 3.28 \pm 0.08$, so that s can be taken as having the constant value of 3. For sub-level corrosion due to flow according to laboratory experiments specified in Table III, $s = 1.53 \pm 0.02$; evaluation of the measurements by Daudans [11] provides $s = 1.55 \pm 0.10$, that of the data by Popov [14] $s = 1.48 \pm 0.01$, so that the average value $s = 1.5$. The measurements by other authors [12], [13], [16] yield similar values.

The results of measurements plotted in Fig. 3 indicate that the sub-level corrosion is directly proportional to the rate of glass melt flow. This finding is in a disagreement with the results by Cooper and Kingery [3] who found a relationship in the form $w = u^{1/2}$. The difference is due to different speeds of sample movement and thus to different values of Re . In the measurements by Cooper [3] the Re value was in the range from 10 to 25, in the present experiments it was in the range of 0.02 to 0.07.

The general equations (5) and (6) obtain the following form when adapted for flow corrosion:

$$w_l = K_p \frac{\eta^{m-n} u^n x^{n-1} \Delta c}{\rho_s^{m-n} D^{m-n} \rho_z} \quad (12)$$

Since the diffusion coefficients are difficult to measure, Hrma [5], [7] has replaced them with viscosity using the adjusted Stokes-Einstein equation:

$$D\eta = C. \quad (13)$$

The validity of this equation is not absolute (the C value being dependent on temperature); however, it can be assumed that for a given refractory and for similar glass melts the value of C will not vary substantially within the tem-

perature interval of 1300 to 1500 °C in question. When combining equations (12) and (13), flow corrosion can be described by equation

$$w_l = K_p \frac{\eta^{(2m-n-1)} u^n x^{(n-1)} \Delta c}{\rho_s^{(m-n)} C^{(m-1)} \rho_z} \quad (14)$$

A comparison of the exponents in equation (14) and the experimentally established relations for the effect of speed and viscosity indicate that $n = 1$, $m = 1/4$. Equation (14) thus acquires the form

$$w_l = K_p \frac{C^{3/4} \Delta c \rho_s^{3/4} u}{\rho_z \eta^{3/2}} \quad (15)$$

The effect of geometric dimension is entirely eliminated in equation (15) which is in agreement with practice. The similarly adjusted equation for glass level corrosion has the form

$$w_l = K_h \frac{C^{(1-m)} \Delta c g^n x^{(3n-1)} \Delta \sigma^n}{\eta^{(1-2m+2n)} \rho_z \rho_s^{(m-2n)}} \quad (16)$$

When analyzing this equation it should be assumed that $n = 1/3$ in order to eliminate the length quantity x which has no practical sense; then $m = -2/3$ and the corrosion equation gets the form

$$w_l = K_h \frac{C^{5/3} \Delta c \rho_s^{4/3} \Delta \sigma^{1/3} g^{1/3}}{\eta^3 \rho_z} \quad (17)$$

The experimentally derived equation differs by their exponents from the equations employed so far (1), (3), probably because the latter have been derived for substantially lower Re values; however, they comply with certain analogous relations holding for heat transfer during flow.

Tables II and III summarize the results of experimental measurements and the constants calculated from them. The values substituted were the flow rate $u = 1.57$ cm/s, glass melt density $\rho_s = 2.50$ g/cm³, and the densities of the refractories listed in Table I. Effect of surface tension, characterized by the

parameter $\Delta \sigma = \frac{\sigma_n - \sigma}{\sigma}$, can only be estimated. It is assumed that at the

surface of all the refractories, a layer enriched with about 10 % ZrO₂, 15 % Al₂O₃ was formed at the expense of SiO₂ and the other components. According to calculation the surface tension of this layer amounts to about 378 mN/m at 1,000 °C while the surface tension of the basic glass melt is only about 300 mN/m. Then $\Delta \sigma = 0.26$ and this ratio holds approximately even at the experimental temperatures. From the ratio of the respective constants for glasslevel corrosion rate and flow corrosion rate it is possible to calculate the

ratio $\frac{K_h}{K_p} C^{11/12}$, the value of which is 396, 411 and 362 for materials A, B and C respectively.

At the experimental temperatures the values of diffusion coefficients D vary around 10⁻⁶ to 10⁻⁷ cm²/s, and the saturated concentration of refractory in the glass melt is about 0.1 to 1 g/cm³. To this corresponds the approximate ratio of constants K_h/K_p of about 10⁵, on the basis of which the following relative values of D and Δc were calculated for the temperature of 1400 °C:

Refractory material	D	Δc
<i>A</i>	$5.37 \times 10^{-6} \text{ cm}^2/\text{s}$	0.336 g/cm^3
<i>B</i>	5.58×10^{-6}	0.340
<i>C</i>	4.86×10^{-6}	0.291

The quantity Δc differs with the refractories in question by up to 17 % and decreases roughly proportionally with increasing ZrO_2 content. The quantity D is subject to somewhat smaller changes but in the same sequence.

The analysis of the published corrosion relationships listed in Table IV, does not allow to calculate the constants in equations (15) and (17) owing to the different measuring conditions (speed of revolution, glass melt, relative evaluation, etc.). Since the experiments of one author were always carried out under the same conditions, the results allow to calculate the relative value of constant k , i.e. to eliminate the effect of flow rate, of the evaluation method, of constants K_h or K_k , and that of glass melt density. These values were related to a refractory containing 32 to 33 % ZrO_2 ($k_{\text{rel}} = 1$) which is used as a standard one. Then, for a material containing 41 % ZrO_2 in the flowing melt test, the relative constant k value according to the measurements by Daudans [11] is $k_{\text{rel}} = 0.70$, according to those by Popov [14] $k_{\text{rel}} = 0.72$ and according to the experiments of the present authors $k_{\text{rel}} = 0.71$; the mean value is 0.71 ± 0.01 . For the glass level corrosion of the same material, Sleggs [15] found $k_{\text{rel}} = 0.80$, and the experimental value was $k_{\text{rel}} = 0.67$.

Equations (15) and (17) can be written in the following form for flux line corrosion:

$$w_l = K_h g^{1/3} \frac{C^{5/3} \Delta c \rho_z^{4/3} \Delta \sigma^{1/3}}{\rho_z} \cdot \frac{1}{\eta^3} \quad (17a)$$

and in the following form for flow corrosion:

$$w_l = K_p \frac{C^{3/4} \Delta c \rho_z^{3/4}}{\rho_z} \cdot \frac{u}{\eta^{3/2}} \quad (15a)$$

The corrosion rate is always proportional to the constant characterizing the type of corrosion, to the term characterizing the type of refractory and that of the glass, and to the term characterizing the effect of the conditions such as viscosity, speed, distance. The constants characterizing the effect of refractory material cannot be interchanged, not even in relative formulation. The expression for density flow under level can be obtained on the basis of equation (7).

CONCLUSION

On the basis of a theoretical analysis, experimental measurements and an analysis of published corrosion curves it was found that the rate of corrosion of a refractory in glass melt was a function of glass melt viscosity. The corrosion rate is proportional to the expression $1/\eta^s$ where the exponent s differs for different types of corrosion. In the case of corrosion in very slowly flowing media the sub-level corrosion is proportional to the melt flow rate. The equ-

ations which have been derived on the basis of these findings allow to calculate corrosion rates under various conditions. Each corrosion mechanism can be described by a different equation.

LIST OF SYMBOLS

- A, B — constants in equation (9) for viscosity calculation.
 C — material constant for the given refractory and glass melt defined by equation (13) — $g\text{ cm/s}^2$.
 Δc — $c_n - c$ is the difference between saturated and initial, concentration of dissolved refractory in glass melt, g/cm^3
 D — diffusion coefficient, cm^2/s ,
 g — gravity constant, cm^2/s ,
 K, k — constants,
 m, n — exponents in equations (5) and (6),
 P — constant in equation (10),
 s — exponent in equation (8),
 t, T — temperature in $^{\circ}\text{C}$, or absolute temperature in K ,
 u — rate of glass melt flow along refractory, cm/s ,
 W_g — corrosion rate by wt., $g/\text{cm}^2\text{ s}$,
 w_l — corrosion rate by length, cm/s ,
 x — distance from the edge of corroded area, cm ,
 ν — kinematic viscosity, cm^2/s ,
 $\Delta \rho = \frac{(\rho_n - \rho)}{\rho}$ — relative change in melt density due to dissolved corrosion products,
 $\Delta \sigma = \frac{(\sigma_n - \sigma)}{\sigma}$ — relative change in surface tension of glass melt due to corrosion products,
 ρ_z — density of refractory material, g/cm^3 ,
 ρ_g — density of glass melt, g/cm^3 ,
 δ_{ef} — effective thickness of boundary layer, cm ,
 η — dynamic viscosity, $\text{dPa} \cdot \text{s}$,
 Indexes:
 h — glasslevel corrosion (flux-line corrosion),
 p — melt flow corrosion (below-level corrosion),
 n — saturated solution.

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KINETIKA ROZPOUŠTĚNÍ ŽÁROVZODORNÝCH MATERIÁLŮ VE SKLOVINĚ

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Rychlost koroze žárovzodorných materiálů ve sklovině je řízena difúzí, pro niž platí Noyes-Nernstova rovnice (4). Přitom je tloušťka mezní vrstvy funkcí Schmidtova a Reynoldsova či Grashoffova kritéria podle rovnice (5) a (6).

Korozní rychlost u hladiny a pod hladinou byla zjištěna u tří elektrotavených žáromateriálů, uvedených v tabulce I. Měřeno dynamickou tyčinkovou zkouškou v závislosti na viskozitě skloviny a na rychlosti jejího pohybu. Dále byl proveden rozbor většího množství publikovaných měření korozní rychlosti v závislosti na teplotě skloviny.

Ve všech případech závisí lineární korozní rychlost na viskozitě skloviny podle rovnice (8):

$$w = \frac{k}{\eta^s}.$$

Exponent s činí u hladinové koroze $s = 3$, u koroze proudící sklovinou $s = 3/2$. Rychlost koroze pod hladinou je lineární funkcí rychlosti proudění skloviny.

Porovnáním odvozených a experimentálně zjištěných závislostí byly odvozeny rovnice pro výpočet korozní rychlosti u hladiny (17) a při korozi prouděním (15a), skládající se vždy ze tří členů — jednoho, který charakterizuje druh koroze, druhého charakterizujícího materiál a třetího určujícího vliv podmínek koroze. Faktory charakterizující vliv materiálu jsou pro každý mechanismus koroze jiné.

- Obr. 1. Rychlost koroze žáromateriálů u hladiny bílé tabulové skloviny v závislosti na její viskozitě. Zkoušené materiály jsou uvedeny v tab. I; O = materiál A, + = materiál B, x = materiál C.
Obr. 2. Rychlost koroze žárovzodorných materiálů pod hladinou bílé tabulové skloviny v závislosti na její viskozitě. Měření provedeno při rychlosti proudění 1,57 cm/s.
Obr. 3. Rychlost koroze žáromateriálů pod hladinou bílé skloviny v závislosti na rychlosti proudění skloviny. Provedeno při teplotě 1500 °C, tj. při viskozitě 110 dPa.s.
Obr. 4. Korozní rychlost různých žárovzodorných hmot v bílé sklovině v závislosti na teplotě podle publikovaných měření různých autorů. Výklad ke křivkám uveden v tab. IV.

КИНЕТИКА РАСТВОРЕНИЯ ОГНЕУПОРОВ В СТЕКЛОМАССЕ

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Скорость коррозии огнеупоров в стекломассе управляется диффузией, для которой справедливо уравнение Ное-Нерста (4), причем толщина предельного слоя является функцией критерия Шмидта и Рейнольдса или Грасгоффа согласно уравнению (5) и (6).

Скорость коррозии у уровня стекломассы и под ним устанавливали у трех электроплавленных огнеупоров, приводимых в таблице I. Измерение проводили на основании динамического метода в зависимости от вязкости стекломассы и скорости его движения. Далее проводили анализ большего количества опубликованных результатов измерения скорости коррозии в зависимости от температуры стекломассы.

Во всех случаях линейная скорость коррозии зависит от вязкости стекломассы согласно уравнению (8):

$$w = \frac{k}{\eta^s}$$

Показатель s у коррозии на уровне стекломассы $s = 3$, у коррозии под уровнем стекломассы $s = 3/2$. Скорость коррозии под уровнем является линейной функцией скорости потока стекломассы.

Сопоставляя выведенные и экспериментальным путем установленные зависимости, авторы выводят уравнения для расчета скорости коррозии у уровня (17) и при коррозии потоком (15а), состоящейся всегда из трех членов, т. е. первого, характеризующего вид коррозии, второго, характеризующего материал, и третьего, определяющего влияние условий коррозии. Факторы характеризующие влияние материала для каждого механизма коррозии различны.

Рис. 1. Скорость коррозии огнеупоров у уровня белой листовой стекломассы мм/день в зависимости от ее вязкости. Исследуемые материалы приводятся в табл. I.; O — материал A; + = материал B; x = материал C.

Рис. 2. Скорость коррозии огнеупоров под уровнем белой листовой стекломассы мм/день в зависимости от ее вязкости. Измерение проводили при скорости потока 1,57 см/с.

Рис. 3. Скорость коррозии огнеупоров под уровнем белой стекломассы мм/день в зависимости от скорости потока стекломассы м/час. Измерение проводили при температуре 1500 °C, т. е. при вязкости 110 dPa.s.

Рис. 4. Относительная скорость коррозии разных огнеупоров в белой стекломассе в зависимости от температуры согласно опубликованным измерениям, проводимым разными авторами. Объяснение кривых приводится в табл. IV.