CERAMICS — Silikáty 35, s. 21—31 (1991)

# MAIN TECHNOLOGICAL CHARACTERISTICS OF GLASS TANK MELTING ZONES FROM THE STANDPOINT OF THE COURSE OF THE MELTING PROCESS

## Part IV. Application of Numerical Results to Real Melting Zones

LUBOMÍR NĚMEC, SIMONA LAURENTOVÁ

*Institute of the Chemistry of Glass and Ceramic Materials, Czechoslovak Academy of Sciences, Lipová 5, 120 00 Prague 2*

*Institute of Chemical Technology, Department of Silicate Technology, Suchbátarova 5, 166 28 Prague 6*

Received 5. 4. 1990

*The relations between the results calculated in Parts II and III [2, 3] for the model device and the basic melting characteristics (specific energy consumption and output) of a real melting tank furnace can be expressed by means of the model device. With real tank furnaces the values of the fictive dead zones are high (0.7—0.8) and indicative of considerable reserves, especially as regards the course of flow, which mostly involves a large proportion of recycling melt. The reserves can be reduced above all by means of mathematical models of the melting zones. As indicated by the graphic representation of the cutting down of the reserves in Figs. 1 and 2, an economic way is provided by raising the output of the melting zones while not decreasing the melting temperatures.*

## INTRODUCTION

The results of calculating the specific energy consumption and output of the model device reported in [1—3] are applicable to real melting tanks in the case when the factor being investigated affects the microprocesses. An example is provided by studying the effect of sand granulometry or refining agent concentration on the given quantities Q (specific energy consumption) and output. If the macroprocesses are influenced, the values of the quantities being investigated depend substantially on the geometry of the melting zone and the macroconditions (shape of the temperature and flow fields). Let us introduce the necessary assumption that the geometrical shape of the tank remains the same as in [1—3] (to make a comparison possible) but that the conditions inside the device approach the real ones (for example, the assumption of isothermal melting and piston flow does not hold). Let us attempt an estimate of changes in the calculated values of specific energy consumption and output.

## THEORETICAL

### There is no piston flow in the melting zone, the temperature is constant.

For this case, the value of constant $K$ in the equation

$$\bar{\tau} = K\, \tau_{tech} + \tau_{res}. \tag{1}$$

is not equal to unity, as was assumed in the calculations. The diflerences between the individual paths in the active part of the device are given by flow rate distribution, which, however, is unknown. According to Cooper [4], it is possible to obtain, using the measured time of passage, i.e. in our case when $\tau_{res}$ in equation (1) is zero and the time of passage is $\tau_{tech}$, the mean residence time $\bar{\tau}$ by means of the approximate expression $\bar{\tau} = (1.5 \text{ to } 2.1)\ \tau_{tech}$. This estimate allows the values of specific energy consumption $Q$ and those of output in the tables in the Appendix [10] to be recalculated for the case of constant temperature if the liquid of the active part does not move by piston flow. On choosing the value of $K$, one can determine the fictive value of the dead zone which, at a given dead zone value in the case of piston flow [2, 3] will also express the effect of different path quality on the values of $Q$ and output. On choosing $K = 2$, the conversion relation is then given by the equation

$$m' = (1 + m)/2. \tag{2}$$

The relationship between $m'$ and $m$ is given in Table I.

*Table I*

Relationship between the fictive value of the dead zone m′ expressing the different rates of flow along the individual paths and the actual value of the dead zone for K = 2

| $m$ | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $m'$ | 0.60 | 0.55 | 0.60 | 0.65 | 0.70 | 0.75 | 0.80 | 0.85 | 0.90 | 0.95 | 1 |

There remains the question over what range one can expect the values of the actual proportions of dead zones m in melting zones to vary. While Smrček [5] reports from experiments on real tanks the values ranging from 0.12 to 0.23, Krushevski and Harasimovich [6] specify $m = 0.09$ to 0.40, Tuzsynski [7] reports m = 0.88 Wojcicki [8] $m = 0.53$. The m value depend much on the type of the tank; Table I shows that the values of the fictive dead zone (volume) will range from 0.55 to 0.85. This means that in the case of real flow and actual dead zone m the values of $Q$ and output listed in the diagrams in [2, 3] will be found for the increased values of $m'$ according to equation (2).
Example: If the actual value of the dead zone is equal to 0.2, then the respective values of $Q$ and output for the real flow will be found at m′ in the diagrams in [2, 3].

## The temperature is not constant in the melting zone

Most real melting zones are not isothermic in character. On the basis of experiments with radioactive tracers, some studies specify a relationship betwen the time of passage and the mean residence time $\bar{\tau}$. The time of passage is understood to be the shortest time of residence of a glass melt element in the melting zone. For example, Smrček [9] suggests the following equation on the basis of investigations on several tank furnaces: $\tau_{pas} = 0.12\ \bar{\tau}$. Similarly, Krushevski and Harasimovich [6] specifiy the value of the numerical constant over the range from 0.08 to 0.15. What is the cause of the great difference between $\bar{\tau}$ and $\tau_{pass}$? According to Cooper, this difference, even for channels through which a liquid flows under non-isothermic conditions, is roughly given by the equation $\tau_{pass} = 0.5\ \bar{\tau}$, where the ratio applies only to forward movement. The much larger difference in the case of real tanks is therefore due to recycling of the melt. This means that in addition to the actual dead zones where virtually no exchange with the active part takes place, there is a large proportion of the tank capacity where the exchange is limited, i.e. occurs only after several cycles of the melt. The melt recycling, which concerns an obviously substantial part of most tanks with respect to their capacity, is responsible for a considerable increase of $\bar{\tau}$ values, and thus also of energy consumption and reduction of output compared to the idealized state $\tau_{pass} = \bar{\tau} = \tau_{techn}$ whose results are listed in the tables in Appendix [10] and in the figures in [2,3]. What are the relations between $\tau_{pass}$ and $\tau_{techn}$ in real tanks? On considering the case of „little non-isothermic courses" (such as with some electric tanks) it may be assumed quite safely that $\tau_{pass} = \tau_{techn}$. The mean value at which the losses are calculated, does not differ much from the mean temperature at the flow path characterized by the time of pasage. The relationship between the fictive value $m'$ and the actual value $m$ in the case when recycling is taken into account and Smrček's relation $\tau_{pass} = 0.12\,\bar{\tau}$ is accepted, is then given by the equation

$$m' = (m + 7.33)/8.33. \tag{3}$$

The relationship between $m'$ and $m$ is given in Table II.

*Table II*

Relationship between the fictive dead zone value $m'$ expressing the effect of recycling at inconstant temperature and the actual value of the dead space. $\tau_{pass} = 0.12\,\bar{\tau}$

| $m$ | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $m'$ | 0.88 | 0.89 | 0.90 | 0.92 | 0.93 | 0.94 | 0.95 | 0.96 | 0.98 | 0.99 | 1 |

On employing the value $m = 0.2$ published in the literature for a real tank [5] and using the also published relationship between $\tau_{pass}$ and $\bar{\tau}$ [9], we can seek the respective values of energy consumption and output in [2, 3] for the value of $m' = 0.9$ under otherwise the same conditions. The values of melting temperatures represent the mean values.

If the melting is distinctly non-isothermic, the time of passage obtained is given by the inequality

$$\tau_{pass} \geqq \tau_{techn.\,pass.} \tag{4}$$

This is the case because the critical melting path may be different from the fastest path, so that a reserve occurs in the fastest path:

$$\tau = \tau_{techn.\,pass} + \tau_{res.\,pass}. \tag{5}$$

$\tau_{res.pass.} = 0$ when the case is approximately isothermic.
If $\tau_{res.pass.} > 0$, the following cases are distinguished:

(a) If the fastest path is not at the same time the critical one and the mean temperature at which the losses are calculated (mean temperature of the melt boundary) is close to the mean temperature at the fastest path, then the losses as well as the mean time of residence are calculated at the same temperature. In this case, the $m'$ values will be still somewhat higher than would correspond to Table II (at the same $\bar{\tau}/\tau_{pass}$ ratio), i.e. the respective energy consumptions are also higher and the output lower than in the approximately isothermic case.

(b) If the fastest path is simultaneously the critical one ($\tau_{res.pass} = 0$, $\tau_{pass.} = \tau_{techn.pass}$) but the mean temperature at the critical path differs from the mean melt-boundary temperature, the losses and $\bar{\tau}$ should be calculated at different temperatures.

(c) If the fastest path is simultaneously the critical one and the mean temperature at the critical path does not differ from the mean melt-boundary temperature, then similarly to the case (a), $\tau_{res.pass} > 0$ and the losses and $\bar{\tau}$ are calculated at different temperatures (case (b)).

The cases ad (a) and (b) involve the difficulty that the relationship between the mean temperature at the fastest path and the mean temperature of the melt boundary is usually unknown. However, experience with large glass tanks shows that the mean temperatures at the so-called open streamlines are comparatively low (for example, in the Float tank, according to the results of mathematical modelling, they range between 1 200 °C and 1 300 °C) in the melting zone, [11], and probably differ very little from the mean melt boudary temperature. This is why the results of calculation of $Q$ and output, obtained by means of the physical model or measured on a long tank operated at constant temperature at values of $m$ of about 0.9, are well applicable as first approximation even in non-isothermic cases. The numerical values in references [2], [3] and in the tables enclosed to report [10] are indicative of great reserves in the operation of present-day melting tanks. As has already been mentioned, glass melt recycling n the melting zone is mainly responsible for these reserves.

## Application of intensifying factors in real melting zones

As follows from the theoretical section [1], in applying any intensifying factor of those summarized in [1] (Fig. 1) and partially investigated in [1—3], it is necessary to meet the requirement for completion of all the main melting processes. There arises the problem how to utilize actually the energy (and output) reserve produced by application of some intensifying factor. In principle, the favourable effect of a given factor may only bring about improved quality of the glass melt (this case will not be considered) or raise the tank output, or allows the energy input to be reduced, or both at the same time. However, technological practice shows that utilization of some of the ways is not arbitrary.

The diagram in Fig. 2. allows the conditions under which the reserves can be utilized, to be specified at least qualitatively. In order to base the problem on real values, the respective curves were calculated for a model of a continuous tank operating at constant temperature, whose melting zone is shown in Fig. 2 [1]. However, the course of the respective curves is very similar to those of other furnaces. In the calculations of specific energy consumption, use is always made of the so-called standard setting, i.e. the case when the last sand grain or seed get exactly to the throat, but do not enter it. This setting corresponds to reserve-free melting (equation (1)).

Fig. 1 show a plot of specific energy consumption vs. temperature for standard setting, isothermic melting and the model. Curve *1* (full line) holds for the dissolution of sand with the effective largest grain diameter of 0.5 mm (Float glass), curve *2* (full line) for 0.3 mm. Elimination of the coarser grain fractions is thus an example of an intensifying factor or measure. The dashed lines in Fig. 1 represent specific energy consumption for refining (elimination of seed). The $t_N$ value designates the nucleating temperature at which heterogeneous nucleation of bubbles on sand grains begins and the additive relation

$$\tau_{\text{techn.}} = \tau_D + \tau_{RN} \tag{6}$$

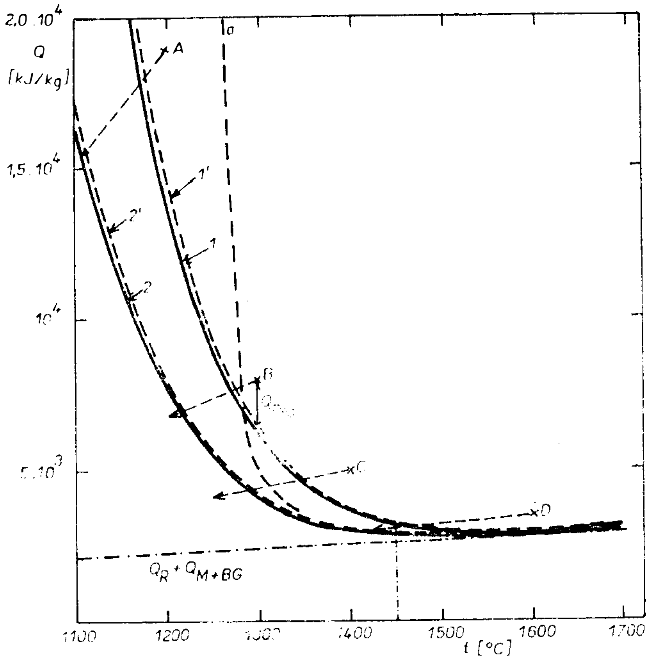


*Fig. 1. Plotting the ways of decreasing specific energy consumption with the use of an intensification factor (reducing the maximum sand grain size) in the model operating at constant temperature.*
*1, 2 — specific energy consumption for sand grains 0.5 mm and 0.3 mm in initial size*
*A, B, C, D — starting points for reducing the specific energy consumption,*

begins to hold. The sum $\tau_D + \tau_{RN}$ is then made use of in the calculations. At lower temperatures, the elimination of seed and dissolution of sand grains take place simultaneously, and in calculating $Q$, use will be made of the longer of $\tau_D$ or $\tau'_D$ (cf. [1]). It should be pointed out that at the lower temperatures, the refining curve obtained is quite inaccurate owing to the possibilities of the experimental methods employed. The points situated below the respective curves for sand dissolution or refining thus indicate impermissible states characterized by occurence of sand grains or seed in the glass melt (e.g. *A* is characterized by content of seed), while the points above the curves (*B, C, D,* ) represent admissible states free of inhomogeneities. The distance of these points from the rescpective curves, with respect to the y ordinate, indicates the energy reserve of the given state ($Q_{res}$). All the points situated on the respective lines thus indicate a reserve-free state.

It is possible to move in various directions from the respective points *A*, *B*, *C*, *D* representing melting at constant temperature with the respective reserve of energy (point *A* has a reserve only with respect to sand dissolution). Particularly two ways are of interest. The way perpendicularly downwards is that to increasing output at constant temperature, those to the left and downwards (steeper at lower temperatures) are the calculated ones towards decreasing the temperature while keeping the output constant. Both ways lead to a decrease of specific energy consumption. All the other ways at sharp angles between the two ways are mixed ones, based on simultaneous increase in output and decrease of temperature. Let us start from point *A*. The state has obviously a reserve with respect to sand dissolution but lies below the refining curve, i.e. the melt contains seed and the state is thus inadmissible. Point *B* lies above both curves, so that movement along both ways is possible. The way towards increasing output leads up to curve 1; however, the constant temperature way allows only a slight reduction of the reserve to be achieved as the refining curve *a* is soon intersected. Both ways from points *C* and *D* terminate at the sand dissolution curve. It appears that with the exception of very high melting temperatures, the ways towards raising the output at constant temperature must be always more advantageous with respect to energy consumption. On reducing the radius of the largest sand grain (or undertaking another intensifying measure) one obtains curve *2*. The specific energy consumption can be reduced in the same way as in the previous case. However, the state given by point *A*, like in the case above, is inadmissible owing to the occurence of seed. The way of decreasing temperature from point *B* does not provide any greater saving than in the previous case, because one encounters the same refining curve *a*; the way of increasing output permits greater savings to be achieved, but it is again terminated by coming to the refining curve below curve *1* (the finer sand can become effective) and the way to increasing the output will get us up to curve *2*. In both instances, from point *D* one reaches almost curves *2*, the energy savings achieved by both ways are almost the same, the output being higher at the higher temperature.

The account given above allows the following conclusion to be made: if the energy consumption is limited below the nucleating temperature of refining, no saving in energy can be achieved by an intensifying measure speeding up the dissolution of sand. Unfortunately, such a case occurs quite frequently in practice and the question is whether such a limitation can be eliminated. If one cannot raise the melting temperature to the value requierd, the refining can be carried out at high temperature in the subsequent reservoir (refining zone). In that case the refining curve *a* will no longer hold up to $t_N$. An intensifying measure is then allowed to proceed up to curve *1* or *2*, and the respective specific energy consumption is given by the distance on ordinate $y$ from the origin to the intersection with dashed lines *1'* or *2'* at the temperature corresponding to the intersection of the chosen way with curves *1* or *2*. In this instance, curves *1'* and *2'* represent the total energy consumption for melting and refining (in our case it is refining at 1 450 °C in a zone of the same size and shape as has the melting zone of the model).

The difference between curves *1'* and 1, and *2'* and 2 specifies the consumption of energy for refining in the second reservoir (refining zone) only; the energy is substantially smaller than that consumed in dissolving the sand. Some numerical results are listed in Table III.

And now about the problem of a glass melt passing through a classical melting tank with a certain temperature schedule. Such an instance is represented in Fig. 2.

*Table III*

Specific energy consuption and specific output of the model after reducing the maximum grain size from 0.5 mm to 0.3 mm (refining can be the limiting factor — cf. Fig. 1), $m = 0.8$, Float glass melt

| Point | Original state | | Way of decr. temper. at constant output | | Way of incr. output at constant temper. | |
|---|---|---|---|---|---|---|
| | $Q$ [kJ/kg] | $P$ [t/m³d] | $Q$ [kJ/kg] | $P$ [t/m³d] | $Q$ [kJ/kg] | $P$ [t/m³d] |
| $A^+$ | 19 000 | 0.14 | 16 000 | 0.14 | 8 100 | 0.45 |
| $B$ | 8 000 | 0.52 | 7 800 | 0.52 | 5 000 | 1.13 |
| $C$ | 5 000 | 1.45 | 4 500 | 1.45 | 3 100 | 6.90 |
| $D$ | 3 500 | 8.05 | 3 050 | 6.05 | 2 900 | 96.00 |

$^+$ the limiting function of refining was not considered, only sand dissolution being taken into accocunt

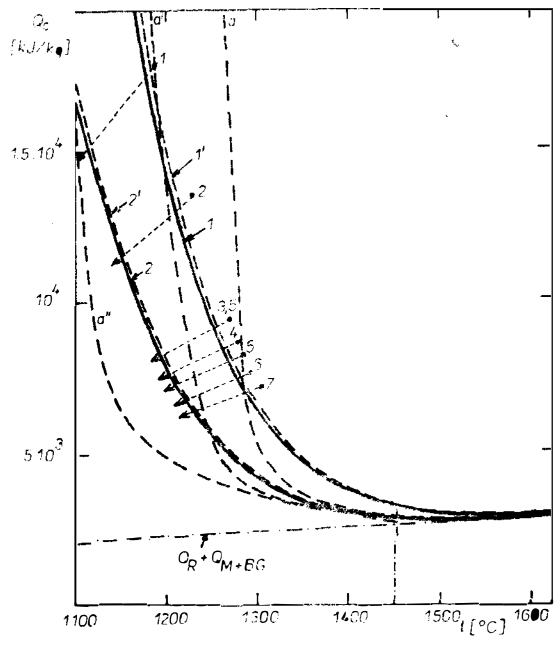


*Fig. 2. Plotting the ways of reducing specific energy consumption with the use of an intensificat-ion factor in a tank operated according to a temperature schedule. 1, 2 — specific energy consump-tion for sand grains having the initial sizes of 0.5 mm and 0.3 mm, 3, 5, 4, 4, 6, 7 — initial points for reducing the specific energy consumption.*

Curves *1* and *2* are the same as in Fig. 1, so that the tank has the same rate of specific losses, the refining curves in the region above $t_N$ are also almost identical with those of the previous case. However, this time the refining curve is not known and its calculation would require knowledge of a large number of data on refining, flow, and their complex calculation. The course of the refining curve can at least be estimated. For the case of absence of a distinct temperature maximum, the same shape of the refining curve as in the previous case is assumed (curve *a*). Points *1, 2, 3, 4, 5, 6, 7* correspond to the energy consumption estimated reserves for various sand paths through the melting zone. The paths were obtained by mathematical modelling of a sheet glass tank and the specific energy consumptions are given at the mean temperatures along the respective paths. Paths *1, 2, 3, 4,* and *5* obviously lie below refining curve *a*. This portion of melt would thus contain seed. An increase in temperature in the zone of the maximum above $t_N$ would shift the refining curve *a* to the left, to *a'*. All of the states *1*—*7* are now admissible, the melt is free of inhomogeneities and the energy consumption can be reduced in the usual way. The possibilities provided by the tank depend of course on that path along which the respective melting or refining curve is reached first. For example with respect to *a'*, point *1* is free of reserves, so that the specific energy consumption of the melting tank cannot be reduced. The other points allow the respective refining or melting curve to be reached. However, particularly the way using decreasing temperature is often limited by refining, as the glass melt has not been heated to an adequately high temperature in the lower layers of the maximum temperature zone. Only by placing the refining curve completely below curves *1* and *2* it is possible to utilize the melting reserves arising in this case by reducing the maximum sand grain radius. The state is represented by curve *a''* and indicates the situation in which the refining ability in the neighbourhood of the maximum has been promoted to a degree when all of the melt at all of the mean melting temperatures will pass through the maximum temperature zone (above $t_N$), so that rapid and perfect refining is ensured. The total specific energy consumptions along the individual paths are then again given by the distance on ordinate y from origin to the intersection with curves *1'* or *2'* at the temperature corresponding to the intersection of the chosen way with curves *1* or 2. The *y* distance between curves *1'* and *1*, or *2'* and *2* gives the specific energy consumption for refining at the temperature maximum. The least advantageous path again limits the possibilities of the way chosen. The state characterized by refining curve *a'* and points *1*—*7* is obviously quite frequent in practice and was probably the cause of failure in the use of classified sands employed with the aim to reduce the specific energy consumption. It may therefore be said that if the dissolution of sand is decisive with regard to specific energy consumption, refining is often the limiting factor of its reduction.

## CONCLUSION

The model dealt with in [1—3] is incapable of taking into account the so-called partial melt recycling which takes place in real tanks, raises considerably the value of energy consumption and cuts down the output. If the relationships and values derived and calculated in parts [1—3] are to be utilized under actual conditions in the absence of piston flow and under non-isothermic conditions, it is necessary to introduce the value of the so-called fictive dead zone, which characterizes the real melting zone. Calculations indicate that for the current dead zone values specified in the literature, the fictive dead zones of real melting tanks are high (about 0.7—0.9) and imply the existence of great reserves in real melting zones. However, in order to utilize these reserves it is primarily necessary to resolve the layout and geometrical shapes of the melting zones, in particular with the use of mathematical models. As indicated by the diagrams obtained, the reserves established should be utilized above all to raise the output of the melting zone while maintaining the respective level of temperatures, rather than to decrease the mean melting temperatures and maintain the constant output.

## References

[1] Němec L.: Silikáty *32* (3), 193 (1988).
[2] Němec L., Laurentová S.: Silikáty *32* (4), 313 (1988).
[3] Němec L., Laurentová S.: Silikáty *33* (2), 105 (1989).
[4] Cooper A.R.: Jour.Amer.Ceram.Soc. *43*, 97 (1960)..
[5] Smrček J.: Sklář a keramik *23*, 270 (1973).
[6] Krushevski K.G., Harasimovich M.: Doklady sekcii 2. SEV ZFI DAW GDR Leipzig. INIS-mf-6311. L-19-79-020077.
[7] Tuszynski W.: Szklo i Ceram. *15*, 2●2 (1984).
[8] Wojcicky J., Sura M., Ksiarek P.: Szklo i Ceram. *17*, 115 (1966).
[9] Smrček J.: Sklář a keram. *23*, 304 (1973).
[10] Němec L.: The main melting processes from the standpoint of energy consumption (in Czech), Research Report DÚ IV-4-3/04 SPZV, Joint Lab. of Sil., Prague 1985.
[11] Němec., Mühlbauer M.: Silikáty *27* (4), 311 (1983).

## List of symbols

$m$ — portion of the dead zone in a real tank
$m'$ — fictive portion of the dead zone including the influence of the real flow, or possibly of non-isothermic conditions
$\bar{\tau}$ — the mean time of residence of the melt in the continuous melting tank [s]
$K$ — dimensionless constant expressing the ratio of the mean time of residence in the melting zone to the time of residence along the critical path [s]
$\tau_{techn}$ — time required for completion of the technological process along the critical path [s]
$\tau_{res.}$ — time reserve of the melting process [s]
$Q$ — mean specific energy consumption for melting [kJ/kg]
$\tau_{pass}$ — the shortest time of passage of a melt element through the thank [s]
$\tau_{techn.pass}$ — technological time of melting along the fastest path [s]
$\tau_{res.pass}$ — reserve along the fastest path [s]
$\tau_D$ — time required for dissolution of solid sand particles (sand-free time) [s]
$\tau_{RN}$ — time required for refining the heterogeneously nucleated seed, [s]
$Q_{res}$ — energy reserve of the given state [kJ/kg]
$t_N$ — temperature at which bubbles (seed) nucleate on sand grains [°C]
$P$ — output of the melting zone [t/24h]
$Q_R$ — specific reaction heat [kJ/kg]

$Q_M$ — specific heat required for heating the melt to the technological temperature [kJ/kg]

$Q_{BG}$ — specific heat dissipated by gaseous products of batch decomposition [kJ/kg]

## HLAVNÍ TECHNOLOGICKÉ CHARAKTERISTIKY SKLÁŘSKÝCH TAVICÍCH PROSTORŮ Z HLEDISKA PRŮBĚHU TAVICÍHO PROCESU

### Část IV: Aplikace numerických výsledků v reálných tavicích prostorech

Lubomír Němec, Simona Laurentová

*Ústav chemie skelných a keramických materiálů ČSAV 120 00 Praha*
*Vysoká škola chemicko-technologická, katedra technologie silikátů, 166 28 Praha*

Výpočty měrných energetických spotřeb a výkonů modelového tavicího prostoru v částech (2, 3) ukazují na významné uplatnění uspořádání proudění projevující se v hodnotě mrtvého prostoru. Vztah mezi použitým modelem a reálným prouděním byl přibližně vyjádřen pomocí tzv. fiktivního mrtvého prostoru reálného tavicího prostoru (viz Tab. I a II), vyjadřujícího vliv recirkulace skloviny a rozdílné kvality drah tavicím prostorem. Pro běžná reálná zařízení vycházejí hodnoty těchto fiktivních mrtvých prostorů vysoké (0.7—0.9) a svědčí o značných rezervách běžných tavicích zařízení. Snižování těchto rezerv je v možnostech především matematických modelů tavicích prostorů. Obr. 1 a 2 a Tab. III ukazují, že intenzifikací získané rezervy je ekonomické využít ke zvýšení výkonu při zachování teplot, nikoliv ke snižování teplot za konstantního výkonu, jak se někdy praktikuje.

*Obr. 1. Zobrazení způsobů snižování měrné energetické spotřeby při uplatnění intenzifikačního faktoru (snížení max. velikosti zrn písku) v modelovém zařízení tavicím za konstantní teploty;*
*1,2 — měrná spotřeba energie pro písková zrna počát. velikosti 0,5 a 0,3* mm
*A, B, C,D — výchozí body pro snižování měrné energetické spotřeby.*

*Obr. 2. Zobrazení způsobů snižování měrné energetické spotřeby při uplatnění intenzifikačního faktoru v zařízení tavicím s teplotním režimem;*
*1,2 — měrná energetická spotřeba pro písková zrna poč. velikosti 0,5 a 0,3* mm
*3,5 4, 5, 6, 7 — výchozí body pro snižování měrné energetické spotřeby.*

## ОСНОВНЫЕ ТЕХНОЛОГИЧЕСКИЕ ХАРАКТЕРИСТИКИ СТЕКЛОВАРЕННЫХ ПРОСТРАНСТВ С ТОЧКИ ЗРЕНИЯ ХОДА СТЕКЛОВАРЕННОГО ПРОЦЕССА IV.

### Использование нуммерических результатов в реальных стекловаренных пространствах

Лубомир Немец, Симона Лаурентова*

*Институт химии стекольных и керамических материалов ЧСАН, 120 60 Прага*
**Химико-технологический институт, кафедра технологии силикатов, 166 28 Прага*

Расчеты удельных энергетических расходов и мощностей модельного стекловаренного пространства в частях (2, 3) являются свидетельством значительного действия упорядочения протока, проявляющееся в величине мертвого пространства. Отношение между применяемой моделью и реальным протоком можно приблизительно выразить с помощью так наз. фиктивного мертвого пространства реального стекловаренного пространства (см. Табл. I. и II.), выражающего влияние рециркуляции стекломассы

и различного количества путей через стекловаренное пространство. В случае реальных установок величины приводимых фиктивных мертвых пространств высоки (0,7—0,9) и являются свидетельством значительных резервов обычных стекловаренных установок. Понижение данных резервов заключается прежде всего в возможности применения математических моделей стекловаренных пространств. Рисунки 1 и 2 и Табл. III. показывают, что интенсификацией полученные резервы можно экономически использовать для повышения мощности при соблюдении температур, а не для понижения температур при постоянной мощности, с чем не раз можно встретиться на практике.

*Рис. 1. Изображение способа понижения удельного энергетического расхожа при применении интенсификационного фактора (понижение максимального размера зерен песка) на модельной стекловаренной установке, работающей при постоянной температуре: , 2 — удельны] расход энергии для зерен песка с исходным размером 0,5 и 0,3 мм: A, B, C, D — исходные точки для понижения удельного энергетического расхода.*

*Рис. 2. Изображение способов понижения удельного энергетического расхода при применении интенсификационного фактора на стекловаренной установке с температурным режимом: 1,2 — удельный энергетический расход для зерен песка с исходным размером 0,5 и 0,3* мм, *3, 5, 4, 5, 6, 7 — исходные точки для понижения удельного энергетического расхода.*