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Predicting the Indicators Characterizing the Water Decarbonization Efficiency when Using Atmospheric-Pressure Thermal Deaerators without Subjecting Water to Steam Bubbling in the Deaerator Tank

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Abstract—The results obtained from combined numerical and experimental investigations of the water decarbonization process carried out in atmospheric-pressure deaerators without subjecting water to steam bubbling in the deaerator tank are presented. More exact values of the hydrocarbonate thermal decomposition rate have been obtained, and the hypothesis about a change of the process governing mechanism in shifting to low total alkalinity values of deaerated water has been proven in the course of these investigations. A procedure for predicting the indicators characterizing the water decarbonization efficiency in using deaerators is proposed based on the obtained study results. The developed procedure features the maximally possible accuracy that can be achieved at the metrological characteristics of the standard alkalinity measurement methods.

Keywords: deaeration, decarbonization, hydrodynamic problem, reaction rate constant, mathematical modeling
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Thermal jet-bubble atmospheric-pressure deaerators are used in preparing makeup water at thermal power plants and for deaerating the feed water supplied to low- and medium-pressure boilers and the makeup water for heat networks. The effectiveness of deaerators in terms of removing corrosive gases from water has an effect on the operating reliability of thermal power equipment and heat networks. It should be noted that both theoretical data [1, 2] and operating experience point to the fact that the deaerator efficiency in regard of removing carbonic acid from water is often the determining parameter: the metal oxygen corrosion rate increases considerably when water contains free carbon dioxide. Carbon dioxide is generated during thermal decomposition of hydrocarbonates and during hydrolysis of carbonates when water is subjected to further heating (after the deaerator), e.g., in steam boilers, and participates in corrosion processes. In view of this circumstance, along with effectiveness of removing free carbon dioxide from water, the deaerator performance efficiency in terms of removing chemically bound forms of carbonic acid is also of significant importance.

The majority of published results from investigations of water deaeration processes and mathematical models developed on the basis of these results open the possibility to calculate the heat transfer and dissolved oxygen desorption phenomena. However, they do not allow the deaerator performance characteristics in terms of removing carbon dioxide to be predicted with the required accuracy. The published data contain certain contradictions relating, in particular, to fitting the models with constants. These drawbacks impose essential limitations on the possibilities of modeling the deaeration processes. As a result, the operating modes of deaeration equipment cannot be adjusted, and—the more so—its designs cannot be improved without carrying out full-scale tests.

In practice, the water decarbonization efficiency in deaerators is characterized separately for free and chemically bound carbon dioxide. In the first case, the concentration of free carbon dioxide in deaerated water is used. The effectiveness of removing chemically bound forms of carbonic acid is commonly estimated by the hydrocarbonate decomposition extent σ, which can be calculated from the total alkalinity A_t^d and from the deaerated water phenolphthalein indicator A_{pp}^d

$$\sigma = 2A_{pp}^d / A_t^d. \tag{1}$$

Previous investigations [3] revealed that deaeration columns, including those fitted with liquid-detaining bubble sheets, have rather poor efficiency in terms of removing free carbon dioxide. It was demonstrated that these features are due to the fact that the actual static conditions for the carbon dioxide–water system are close to the thermodynamically equilibrium conditions with the possibility of transition from the desorption region to the absorption region under the operating conditions of the upper jet compartments. Thus, as far as operation of atmospheric-pressure deaerators is concerned, it is the deaerator tank that bears the main burden in regard of removing free and especially chemically bound carbon dioxide.

Figure 1 shows generalization of the published values of σ for DA-50, DA-300m, and DSA-300 atmospheric-pressure deaerators operating without steam bubbling in the deaerator tank. Traditionally, the parameter σ is represented as a function of time for which water dwells in the deaerator [1, 2, 4, 5]. Obviously, these data cannot be directly used in predicting the deaerator performance efficiency in terms of removing carbonic acid compounds because they are characterized by an essential scatter of values. Apparently, there exist other factors influencing the efficiency of removing bound carbon dioxide from water. For establishing these factors, we consider the mechanism governing irreversible thermal decomposition of hydrocarbonates in subjecting Na-cationated water as the most frequently encountered case:

$$2HCO_3^- \rightarrow CO_3^{2-} + H_2O + CO_2^{aq};$$
$$HCO_3^- + OH^- \rightarrow CO_3^{2-} + H_2O; \qquad (2)$$
$$CO_2^{aq} \rightarrow CO_2\uparrow.$$

For definiteness, we will consider the process in the deaerator tank assuming that, owing to deaeration column operation, the water at the stage inlet is a nonsaturated solution of carbon dioxide. Initially, the free carbon dioxide produced during thermal decomposition of hydrocarbonates is present in water in dissolved form (denoted by the superscript “aq”), and after the solution becomes supersaturated, its dispersed release in the form of gas bubbles begins. The resulting process includes sequentially proceeding stages of chemical conversion, molecular diffusion, and dispersed release of gas, and it should be noted that the second and third stages depend on the hydrodynamic environment in the system. In view of the fact that the temperature in the deaerator tank’s water volume during operation in the adjustment range of deaerator loads is little different from the saturation temperature at the pressure in the tank space above the water level, the molecular carbon dioxide generation rate, which is the first stage of the overall process, should be determined solely by the chemical reaction order.

In the general case, we can assume that the chemical process runs according to a first- or second-order chemical reaction. The kinetic equation is written in the form

$$\frac{dC}{d\tau} = -KC^n, \qquad (3)$$

where C is the mass concentration of hydrocarbonates in water, K is the reaction rate constant, τ is time, and n is the reaction order equal to 1 or 2.

In accordance with the study results reported in [7, 8], the considered process is most likely to proceed as a second-order reaction.

In our previous work [3], we carried out generalization of the published data and the results of additional experimental investigations on determining the hydrocarbonate thermal decomposition rate constant in atmospheric-pressure deaerators [7–9]. For further reasoning, we refer to Fig. 2, which shows the results of an analysis carried out for deaerators operating without steam bubbling in the tank.

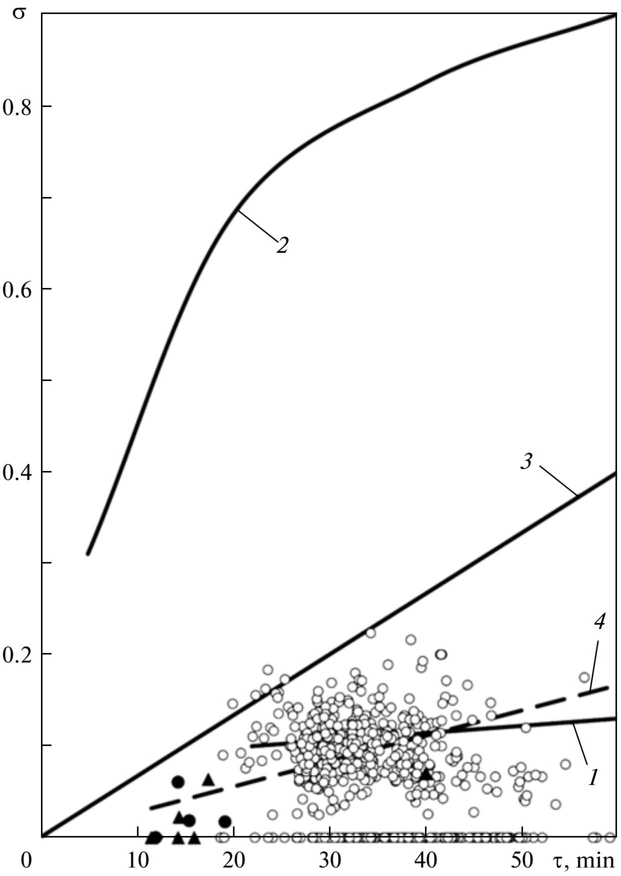

Fig. 1. Degree of hydrocarbonate thermal composition versus the water dwelling time τ in the deaerators. Points are for the experimental data of the authors [3] for different types of deaerators (● DA-300m, ▲ DSA-300, and ○ DA-50), (*1*) TsKTI data [1], (*2*) Tilmans’ data interpreted by I.K. Grishuk (under laboratory conditions) [5], (*3*) data of M.S. Shkrob and Yu.M. Kostrikin [4, 6], and (*4*) approximation of the authors’ experimental data [3] (according to the least squares method without taking into account zero values of σ).

The scatter of the obtained values of K may be due to the metrological characteristics of the methods for quantitative chemical analysis and measurements of thermal parameters, incompleteness of the previously adopted hypothesis (2) about the mechanism governing the thermal decomposition of hydrocarbonates in a deaerator, or due to variations of the hydrodynamic environment in the tank. The latter point requires some explanation.

The values of the reaction rate constant K calculated from experimental data are the kinetic characteristic of the process running under the particular oper-

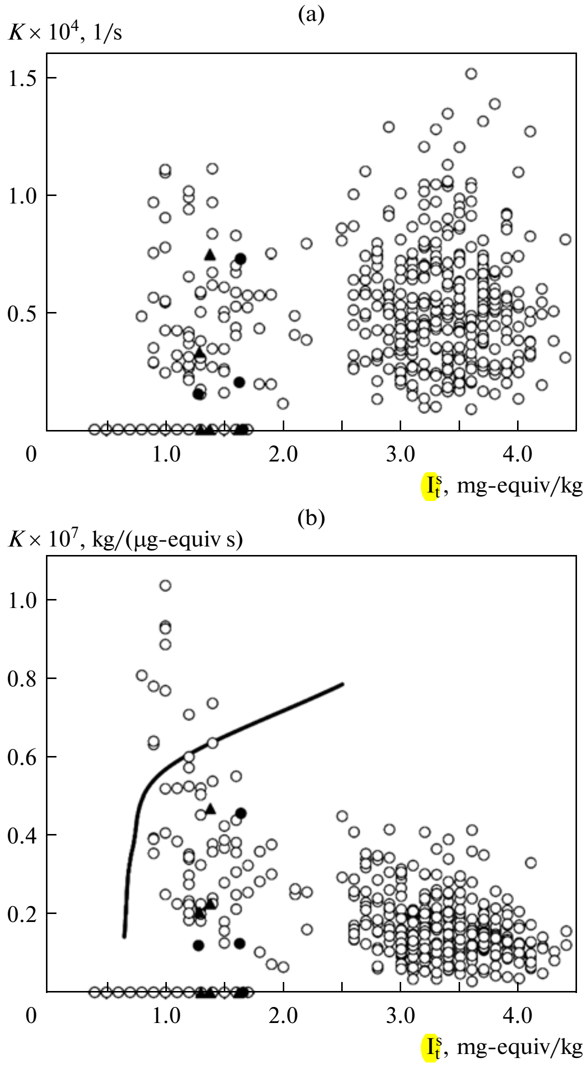

Fig. 2. The hydrocarbonate thermal decomposition rate constant in atmospheric-pressure hydrocarbonates versus the source water total alkalinity without using steam bubbling in the deaerator tank water volume at $n = 1$ (a) and $n = 2$ (b). The curve represents V.A. Permyakov's data [7], and points represent the experimental data of [3] for different types of deaerators: ● DA-300m, ▲ DSA-300, and ○ DA-50.

ating conditions in the deaerator rather than the kinetic characteristic of the chemical process itself; i.e., the value of K takes into account also the hydrodynamic environment in the system. This influence manifests itself in that different elementary water volumes dwell in the tank for different periods of time; hence, the available time of reaction is also different for them. In the considered case, the water dwelling time in the deaerator tank, which is required for calculations after integrating equation (3), was determined as the time of full displacement by dividing the water volume in the tank by the volume flow rate of water through the tank under the conditions of each experiment.

The data presented in Fig. 2 indicate that with the reaction order $n = 1$ the scatter of K values with respect to their average level becomes noticeably larger at $A_t^s >$ 2.3 mg-equiv/kg. However, at lower alkalinity values this statement is not obvious. The available data confirm the hypothesis outspoken in [7, 8] about the thermal decomposition of hydrocarbonates as a second-order reaction at $A_t^s > 2.3$ mg-equiv/kg. With lower alkalinity values, a change in the process governing mechanism can be expected. For drawing a final conclusion in this regard, statistical hypothesis analysis methods should be used.

In view of the results of previous investigations outlined above, the objectives of the present work were formulated:

(i) to process the results of experimental investigations taking into account different periods of time for which different elementary volumes of water dwell in the deaerator tank for determining more exactly the value of the hydrocarbonate thermal decomposition rate constant;

(ii) to carry out a statistical analysis for determining how significant the refinement of constants in the model is; and

(iii) to perform a statistical check of the hypothesis about a change of the process governing mechanism (the order of the reaction in its chemical stage) in decreasing the total alkalinity of deaerated water.

The first of the above-mentioned objectives was solved using the FlowVision application software system (version 3.08.03) [10], which is intended for numerically modeling 3D laminar and turbulent, steady and unsteady flows of fluids using the finite volume method with applying high-precision difference schemes and appropriate mathematical models describing the relevant physical processes.

For carrying out numerical experiments, a simplified deaerator tank model was developed for each of the considered deaerators. Figure 3 shows an example of such model for a DSA-300 deaerator. In view of the fact that a single-phase flow of incompressible fluid was modeled at the given stage of investigations, the phase interface surface in the deaerator tank geometrical model was represented by an ideal wall (the slip condition).

The physical model is specified by the following parameters: the substance is water, the aggregate state is liquid, the phase is continuous one, the motion parameters correspond to a Newtonian liquid, and the turbulence is represented by a standard k–ε model.

The boundary conditions are selected in accordance with the actual parameters characterizing the operation of deaerators in the experimental investigations [3, 9]. The boundary conditions adopted in the deaerator tank analysis model are listed in Table 1.

The FlowVision software system uses a Cartesian locally adaptive computation mesh. The initial mesh is specified as a uniform one with a size of 20 × 20 × 60 cells. Taking into account the mesh geometry resolution function, the final number of cells used in the calculations for the conditions of different experiments varied from 42 134 to 60?986. The calculation convergence was estimated from the medium pressure discrepancies in the model inlet section and the velocity in the model outlet section.

In particular, the distribution of water velocities in the deaerator tank was determined in the calculations. The "Current lines" layer was used as a tool for visualizing the calculation results. Figure 3 shows an example of current lines family for the "Velocity" variable, which originate from the inlet section.

For solving the specified objective of refining the reaction rate constant value, it is necessary to determine the time taken for elementary volumes of liquid to travel along each current line. The FlowVision software system makes it possible to upload the values of the "Maximal time" and "Maximal path" variables over the entire "Current lines" (line family) layer and does not allow the above-mentioned parameters to be simultaneously uploaded for a separate current line. In view of this feature, the calculation results were processed as follows.

The inlet section was subdivided into m areas. A "Sphere" object was placed in the middle of each section, which was assigned to be the source of a single current line. The value of the "Maximal time" variable was uploaded for the "Current lines" layer containing a single line. Thus, the values of time τ_i for which each of m separated water volumes dwelled in the deaerator tank under the conditions of each experiment were obtained.

The value $m = 1000$ adopted for further calculations was selected based on the results of special investigations, during which it was revealed that at $m = 500$ the calculated values of reaction rate constant differ from those obtained at $m = 1000$ by more than 4%. At the same time, when the number of separated volumes increased to $m = 1500$, the deviation of the reaction rate constant was less than 0.2%.

The refined value of the hydrocarbonate thermal decomposition rate constant was determined proceeding from the assumption that it should be the same for all current lines because the temperature of water in the tank is the same at all points. In this case, the final concentration of hydrocarbonate C_i, μg-equiv/kg in the ith water volume will be

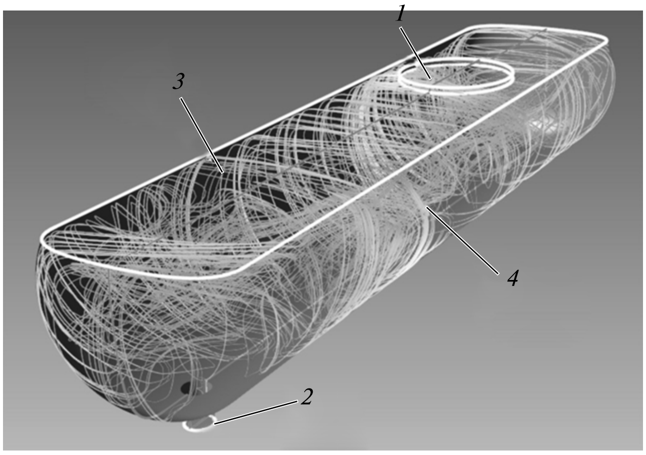

Fig. 3. A simplified geometrical model of the DSA-300 deaerator's tank and an example of current lines family. (*1*) Inlet section (the "Inlet" boundary condition), (*2*) outlet section (the "Outlet" boundary condition), (*3*) wall modeling the free surface (the "Wall 1" boundary condition, and (*4*) deaerator tank wall (the "Wall 2" boundary condition).

$$\text{at } n = 1 \quad C_i = C_0 \exp(-K_{n=1}\tau_i), \tag{4}$$

and

$$\text{at } n = 2 \quad C_i = \frac{1}{\frac{1}{C_0} + K_{n=2}\tau_i}, \tag{5}$$

where C_0 is the initial concentration of hydrocarbonates in water at the deaerator tank inlet, μg-equiv/kg; $K_{n=1}$ and $K_{n=2}$ are the reaction rate constants having the measurement unit 1/s at $n = 1$ and kg/(μg-equiv s) at $n = 2$; and τ_i is the time for which the ith water volume dwells in the tank, s.

The calculated hydrocarbonate concentration in water in the tank outlet section C, μg-equiv/kg, is determined from the expression

$$C = \frac{1}{m}\sum_{i=1}^{m} C_i, \tag{6}$$

because each ith water volume contains equal quantities of liquid. The total flow rate of water through the tank G is subdivided into m jets with the same flow rate $g = G/m$, kg/s. The refined values of the reaction rate

Table 1. Adopted boundary values

Boundary condition in accordance with Fig. 3	Type of boundary condition	Parameter	Specified conditions
Inlet	Inlet/Outlet	Normal mass velocity	In accordance with the results of experimental investigations
Outlet	Inlet/Outlet	Static pressure	@То же@
Wall 1	Wall	–	Slipping
Wall 2	Wall	–	Adherence

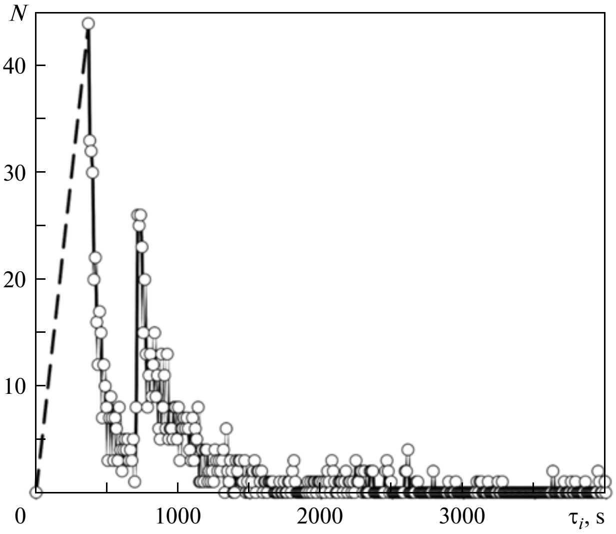

Fig. 4. Distribution of current lines number with respect to water dwelling time in the tank.

constant at $n = 1$ and $n = 2$ were determined using expressions (4)–(6) by selection according to the condition of coincidence of the calculated and experimental values of C.

For example, we consider the calculated values of τ_i obtained for one of the experiments carried out on the DSA-300 deaerator with the water level in the tank $H = 2199$ mm, $G = 64.95$ kg/s, $C_0 = 1330$ μg-equiv/kg, and $C = 985$ μg-equiv/kg. Figure 4 shows the distribution of the current line number N by the water dwelling time in the tank. For more clarity, the time range was decreased, the maximal dwelling time is 10230 s, and the distribution pattern in the range from 3500 to 10?230 s is similar to that in the range from 3000 to 3500 s.

An analysis of the data shown in Fig. 4 allows the following conclusion to be drawn. The distribution of current lines number by the water dwelling time in the tank is deformed toward decreasing. The second (right-hand) maximum is due to formation of a stagnant zone in the deaerator tank's water volume on the side of the deaeration column placed opposite to the tank end face from which the deaerated water is drained. Accordingly, the water dwelling time in the tank calculated as the full displacement time by dividing the water volume in the tank by the volume flow rate of water through the tank is not consistent with the time corresponding to the median of the obtained distribution. As a result, the reaction rate constant values calculated using the two considered methods differ from each other. In the given example, these values are as follows: at $n = 1$, the calculation by the displacement time gives $K = 1.53 \times 10^{-4}$ 1/s, and the calculation according to (4)–(6) gives $K = 2.33 \times 10^{-4}$ 1/s (the mismatch between the values is 52.3%), and at $n = 2$, the calculation by the displacement time gives $K = 0.77 \times 10^{-7}$ kg/(μg-equiv s), and the calculation according to (4)–(6) gives $K = 1.23 \times 10^{-7}$ kg/(μg-equiv s) (the mismatch between the values is 59.7%).

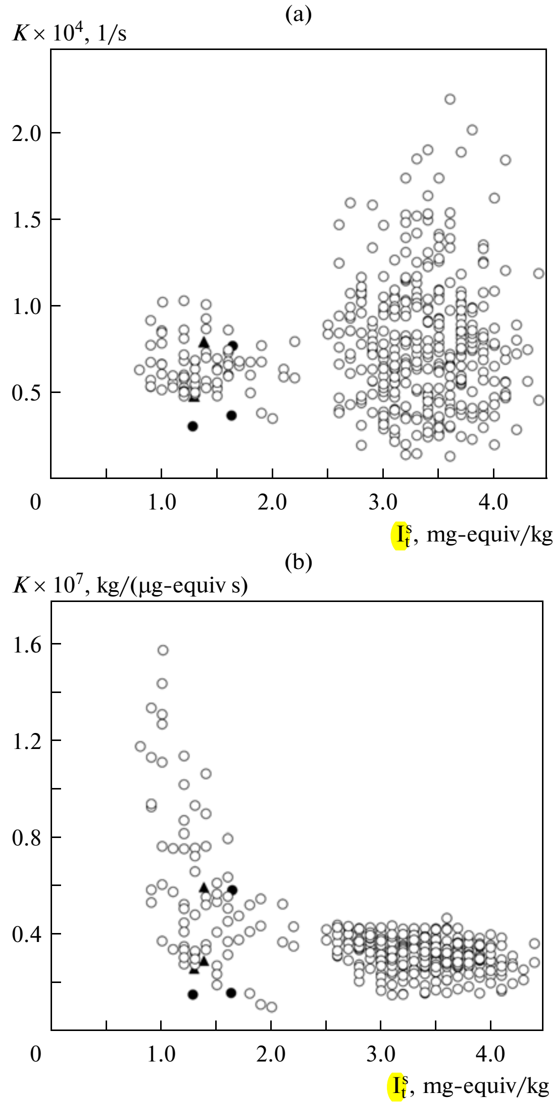

Fig. 5. Results from refining the resulting hydrocarbonate thermal decomposition rate constant in atmospheric-pressure deaerators operating without steam bubbling in the deaerator tank at $n = 1$ (a) and $n = 2$ (b). The notation is the same as in Fig. 2.

The results obtained from refining the reaction rate constant values in all experiments are generalized in Fig. 5. The data of V.A. Permyakov shown in Fig. 2 are in this case excluded because the available initial information is insufficient for generalizing them. The zero values of reaction rate constants are also excluded because they were obtained at zero alkalinity estimated by the phenolphthalein indicator of deaerated water, which introduces uncertainty in the results.

The results from statistical comparison of the data of [11] shown in Figs. 2, 5, as well as the results from

Table 2. Statistical analysis of the obtained results

Question	Answer and its substantiation	Conclusion
1. Do the totalities of reaction rate constant values *K*, 1/s (a first-order reaction) in Figs. 2 and 5 have the same accuracy with the total deaerated water alkalinity $A_t < 2.3$ mg-equiv/kg?	No. The variances with respect to the mean value for the indicated totalities of data are equal to 6.9×10^{-10} $(1/s)^2$ for Fig. 1 and 2.2×10^{-10} $(1/s)^2$ for Fig. 5. Fisher's criterion value is equal to 3.41, which is higher than Fisher's criterion critical value equal to 1.47	The refined values of reaction rate constant *K*, 1/s (a first-order reaction with the deaerated water total alkalinity $A_t < 2.3$ mg-equiv/kg feature better reproducibility than do the values before the refinement. In calculations, it is recommended to use $K = (0.65 \pm 0.14) \times 10^{-4}$ 1/s
2. Do the totalities of reaction rate constant values *K*, kg/(μg-equiv s) (a second-order reaction) in Figs. 2 and 5 have the same accuracy with the total deaerated water alkalinity $A_t > 2.3$ mg-equiv/kg?	No. The variances with respect to the mean value for the indicated totalities of data are equal to 5.9×10^{-17} kg/(μg-equiv s)^2 for Fig. 1 and 4.1×10^{-10} kg/(μg-equiv s)^2 for Fig. 5. Fisher's criterion value is equal to 1.43, which is higher than Fisher's criterion critical value equal to 1.19	The refined values of reaction rate constant *K*, kg/(μg-equiv s) (a second-order reaction with the deaerated water total alkalinity $A_t > 2.3$ mg-equiv/kg feature better reproducibility than do the values before the refinement. In calculations, it is recommended to use $K = (0.32 \pm 0.06) \times 10^{-7}$ kg/(μg-equiv s)
3. Do the totalities of reaction rate constant values *K*, 1/s (a first-order reaction) and *K*, kg/(μg-equiv s) (a second-order reaction) in Fig. 1 (before the refinement) have the same accuracy at the total deaerated water alkalinity $A_t < 2.3$ mg-equiv/kg?	Yes. The variances expressed in relative units for the indicated totalities of data are equal to 0.276 for a first-order reaction and 0.327 for a second-order reaction. Fisher's criterion value is equal to 1.18, which is smaller than Fisher's criterion critical value equal to 1.47	There are no grounds to assume a change in the reaction order of the hydrocarbonate thermal decomposition process chemical stage at the deaerated water total alkalinity A_t equal to around 2.3 mg-equiv/kg
4. Do the totalities of refined reaction rate constant values *K*, 1/s (a first-order reaction) and *K*, kg/(μg-equiv s) (a second-order reaction) in Fig. 5 have the same accuracy at the total deaerated water alkalinity $A_t < 2.3$ mg-equiv/kg	No. The variances expressed in relative units for the indicated totalities of data are equal to 0.048 for a first-order reaction and 0.298 for a second-order reaction. Fisher's criterion value is equal to 6.23, which is smaller than Fisher's criterion critical value equal to 1.47	The hypothesis about a change in the reaction order of the hydrocarbonate thermal decomposition process chemical stage at the deaerated water total alkalinity A_t equal to around 2.3 mg-equiv/kg should be regarded to have been statistically proven

checking the hypothesis about the change of the reaction order in the process chemical stage are summarized in Table 2. The level of significance is taken equal to 0.05 for all cases considered in Table 2. The hypotheses about the process as a first-order reaction at high total alkalinity of water and as a second-order reaction at a low total alkalinity of water are not considered in Table 2: it is obvious that they are incorrect.

The error of determining the reaction rate constants can be estimated as the error of indirect measurements. The calculation is carried out using the alkalinity measurement results according to the phenolphthalein indicator and twice the total alkalinity of deaerated water. The standardized relative error of determining the total alkalinity is 3–7%, and that of determining the alkalinity by phenolphthalein is 9–18% [12]. We take the maximal levels from the above-mentioned values equal to 7 and 18% for total alkalinity and for alkalinity by phenolphthalein. We also take into account the errors of measuring the deaerated water flow rate (1.8%) and water level in the deaerator tank (1.6). With these assumptions, the error of indirect determination of the reaction rate constant resulting from the error of parameter measurement methods in the experiments will make 23% [13].

According to the data of Table 2, the refined error of determining the reaction rate constants estimated using the statistical methods based on the available totality of experimental data was found to be $0.14/0.65 \times 10^2 = 21.5\%$ for the first-order reaction rate constant and $0.06/0.32 \times 10^2 = 18.8\%$ for the second-order reaction rate constant. These values correspond to the error of indirect determination of the reaction rate constant (23%). It should be pointed out that before the refinement carried out using the proposed method (see Fig. 2), the error was equal to 53 and 47%, respectively, for the first- and second-order reaction rate constants, which differs considerably from the error stemming from the metrological characteristics of the applied methods for measuring thermal and chemical parameters.

Thus, it can be believed that the observed in Fig. 5 scatters of the reaction rate constants in the recommended ranges for applying them (see Table 2) are due to the errors pertinent to the methods used for measuring the thermal and chemical parameters of cool-

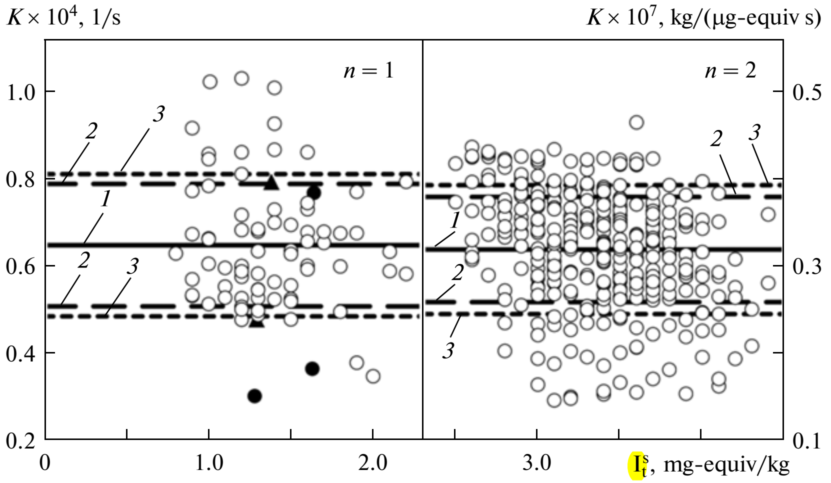

Fig. 6. The experimental and recommended values of hydrocarbonate thermal decomposition reaction rate constants in atmospheric-pressure deaerators operating without steam bubbling in the deaerator tank as functions of the total alkalinity in source water. (*1*) Recommended values; the confidence interval boundaries of the reaction rate constant determination error at the confidence probability equal to 0.95: the recommended values stemming from the metrological characteristics of methods for measuring the chemical (*2*) and thermal (*3*) parameters of coolant flows. The other notation is the same as in Fig. 2.

ants. Further refinement of these data is possible only in case of using more precise measurement techniques, primarily for measuring the deaerated water alkalinity. In view of the fact that online monitoring is carried out using alkalinity measurement techniques corresponding to [12], such additional refinement does make sense from the practical point of view.

Figure 6 shows consolidated data on the experimental and recommended values of hydrocarbonate thermal decomposition reaction rate constants with indicating the ranges in which the process is most likely to proceed as a first- and second-order reaction.

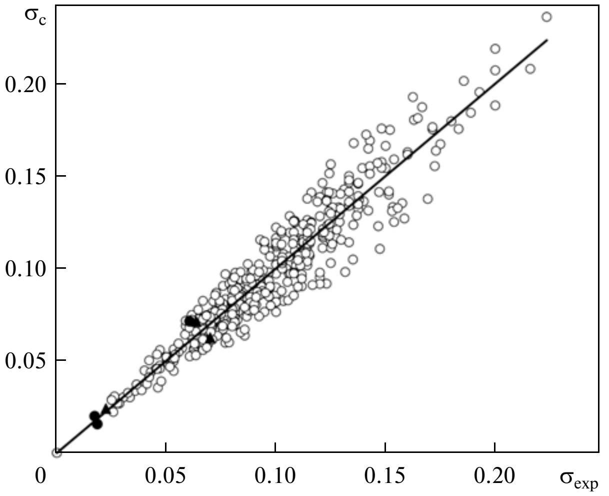

Fig. 7. Comparison between the experimental and calculated values of the extent to which hydrocarbonates are thermally decomposed in atmospheric-pressure deaerators operating without steam bubbling in the tank. The curve corresponds to coincidence of the calculated and experimental data. The other notation is the same as in Fig. 2.

Using the obtained values of reaction rate constants, it is not difficult to determine the extent to which hydrocarbonates are thermally decomposed in a deaerator of the specified design and the deaerated water alkalinity by phenolphthalein using the following general algorithm:

$$K_{n=1,2} = f\left(\mathrm{A}_\mathrm{t}^\mathrm{s}\right); \;\; C_0 \approx \mathrm{A}_\mathrm{t}^\mathrm{s}; \;\; \tau = f\left(G_\mathrm{d}; H\right);$$

$$C = \begin{cases} C_0 \exp\left(-K_{n=1}\tau\right), & \mathrm{A}_\mathrm{t}^\mathrm{s} < 2.3 \ \text{mg-equiv/kg}; \\ \left(1/C_0 + K_{n=2}\tau\right)^{-1}, & \mathrm{A}_\mathrm{t}^\mathrm{s} \geq 2.3 \ \text{mg-equiv/kg}; \end{cases} \quad (7)$$

$$\sigma = 1 - C/C_0; \;\; \mathrm{A}_\mathrm{t}^\mathrm{d} = \left(G_\mathrm{in}\mathrm{A}_\mathrm{t}^\mathrm{s} + G_\mathrm{st}\mathrm{A}_\mathrm{t}^\mathrm{st}\right)/G_\mathrm{d}$$

$$\approx G_\mathrm{in}\mathrm{A}_\mathrm{t}^\mathrm{s}/G_\mathrm{d}; \;\; \mathrm{A}_\mathrm{pp}^\mathrm{d} = \sigma\mathrm{A}_\mathrm{t}^\mathrm{d}/2,$$

where τ is the water dwelling time in the deaerator tank, which is defined as the median of a distribution similar to that shown in Fig. 4 (it is determined for the specified values of operating parameters); G_d, G_in, and G_st are the flowrates of deaerated water, source water, and steam; and $\mathrm{A}_\mathrm{t}^\mathrm{st}$ is the total alkalinity of deaerator heating steam.

Figure 7 shows the results obtained from applying model (7) under the conditions of the experiments carried out by the authors of this article [3, 9], the experimental data on which are shown in Fig. 1 (for more clarity, the data at zero experimental values of σ were excluded). It follows from Fig. 7 that the rms deviation of the calculated values of σ_calc from the experimental ones σ_exp is 12.9%. For comparison, the value of this indicator for a linear dependence of σ on the water dwelling time in the deaerator, the graph of which is depicted in Fig. 1 by curve *4*, is 48,5%.

CONCLUSIONS

(1) Owing to the taking into account of different periods of time for which different elementary water volumes dwell in the deaerator, it became possible to reduce the error of experimentally determining the hydrocarbonate thermal decomposition rate constants on the average from 50.0 to 20.1%, i.e., to the minimal possible value stemming from the metrological characteristics of standard water alkalinity measurement methods. With such refinement, it became possible to reveal and statistically prove the change of reaction order at the process chemical stage with the total alkalinity of deaerated water equal to around 2.3 mg-equiv/kg.

(2) Based on the obtained study results, a procedure for predicting the indicators characterizing the water decarbonization efficiency in deaerators has been developed, the accuracy of which is a factor of 3.7 better than that of existing models.

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Translated by V. Filatov

SPELL: Ok!