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MATHEMATICAL MODELLING OF ABSORPTION COLUMNS I.

THE INVESTIGATION OF THE MODELS OF ABSORPTION COLUMNS

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The aim of the authors was the extensive investigation of the problems emerging in the mathematical modelling of packed absorption columns.

A method will be described which can be used for the determination of the concentration distribution in a packed column. The measured data were processed to these calculations, two models, the Piston Flow model (PF), and the Axial-Dispersed Plug-Flow model (ADPF) were used. The comparison made between the measured and calculated data revealed the fact that the ADPF model fulfils the process with satisfactory accuracy between the examined limits.

If the liquid load of the column is increased, the use of the PF model is also favourable. Both models were used in the determination of the component transfer coefficient. The numerical value of the transfer coefficient ($\beta\omega$) obtained by the calculations based on the ADPF model was twenty or fifty per cent higher than the same one of the PF model.

The mathematical modelling of chemical processes is based on the DAMKÖHLER equations [1], which express the conservation laws. Depending on the real application of these equations, different types of models exist [1, 2].

From other viewpoint, the general equations have to be transformed for the description of a given process, using the information previously obtained in the experiments.The derived equations are in general more or less simpler. It is well known that a simpler model in most cases poorly describes reality, but is easy to handle.

The basic aim was to select a model which works well, where the computation of the results can be carried out quickly and without effort.

In this work, a packed absorption column was investigated. Based on the mentioned mathematical models, the calculated and experimentally determined data were compared and an answer was given for the questions raised previously.

SULPHUR DIOXIDE ABSORPTION IN PACKED COLUMN

Sulphur dioxide is moderately soluble in water, its concentration can be determined - either in liquid or in gas phases - easily and exactly. In view of these favourable properties, this gas was selected from among the others. The equilibrium concentrations of sulphur dioxide existing in the liquid and the gas phase being in contact with each other can be described fairly well by the following equation, which is valid at 15°C and at atmospheric pressure [3, 13]:

$$c_L^* = H\, c_G + c_o^* \tag{1}$$

where $H = 62.3$ and $c_o^* = 0.0084$ (moles per litre).

The Arrangement of the Absorption Column

The experiments were carried out in the absorption column shown in Fig. 1. The column, built up from seven glass tubes, was filled with Raschig rings. The I.D. of the column was 0.1 metre and the packed height was $Z = 2.13$ metres. The dimensions of the Raschig rings were 10 mm o.d. x 10 mm deep x 1 mm thick.

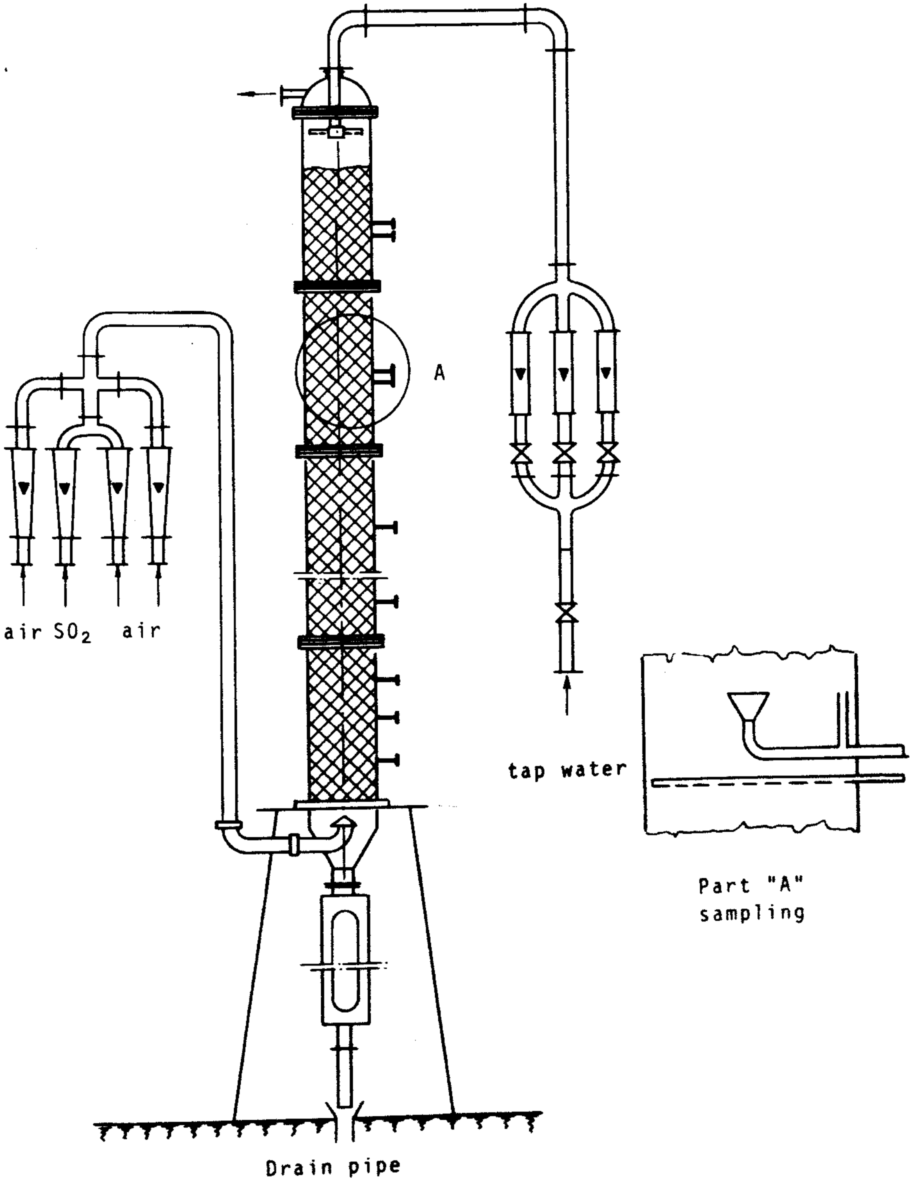

Fig. 1. **Packed absorber**

The solute free liquor - tapwater - was regulated by a valve, it was led through a rotameter and six liquid feed jets built into the top of the column. Through these the water was evenly sprayed over the rings. The amount of the solution, collected at the bottom of the column was held constant by a level controller and the exit solution was led into the drain-pipe.

A gently heated steel bomb was used as the source of sulphur dioxide and the air which was mixed with it was provided by a blower. The flow rate of air was regulated by a valve and measured by a rotameter. The sulphur dioxide containing air was blown into the bottom of the column, it passed upwards through the packings and came into contact with the liquid and finally left the column through the top. In order to obtain detailed information about the running absorption column, it is generally insufficient to determine the compositions of the gas and liquid phases at the top and bottom of the column, but it is necessary to locate several sampling taps along the packed height.

In addition to the construction of the column, the sampling method is important with regard to the accuracy of the measurement.

The Sampling Methods and Analytics

For the determination of the concentration profiles the liquid and gas phases along the packed column, twenty three sampling taps were mounted, among these eleven were used for taking gas, and the remainder for liquid samples.Near to the bottom of the column, the taps were located near to each other, this arrangement made it easier to determine the higher concentration changes that occurred in the phases.

The sampling is accurate if the composition of the sample is the same as the composition of the bulk phase at the level of the sampling tap. This idea was taken into account in the design of the sampling taps which can be seen in Fig.1. In the design of the shape and dimensions of the taps, special care was taken to ensure that they only slinghtly disturb the flow of the phases.

The gas sampling was carried out by a five millimetres I.D. tube, sealed at one end and perforated along its mantle in the direction of the gas flow. This tube was placed at a right angle to the axis of the column. A small baffle plate was soldered on to the tube to prevent the penetration of the liquid into the holes. The gas samples were free of liquid and their composition well represented the streaming gas phase at the given cross section. The volume of the sample is negligible, so the flow conditions were undisturbed.

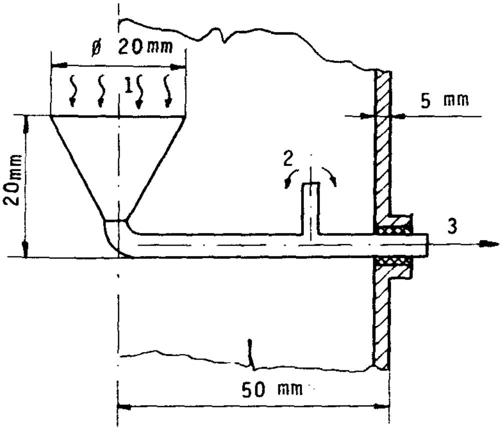

Fig.2. **Method of sampling the liquid phase**

The sampling of the liquid involved some difficulties, because due to the random arrengement of the rings, the flow of the liquid was uneven along the cross section. Therefore, the sampling tube was fitted with a funnel and a pipe stub as shown in Fig.2.

As it can be seen in Fig. 2., the liquid dripping into the funnel (1) flows through the pipe stub (2) mounted upwards and finally it flows back to the packing. Using this arrangement, the liquid sample, taken at certain intervals, well represents the composition of the bulk liquid.

The sulphur dioxide content of both phases was analyzed iodometrically. The gas samples were sucked into an evacuated flask. Care must be taken by the sampling to fulfil the following relation:

$$t \gg 3600\ V/G$$

where t = duration of sampling (sec)

V = volume of the sampling flask (litres)

G = volume flow rate of gas (litres per hour)

If the sampling does not comply with the above requirements, the results are generally incorrect.

Experiments

Experiments were carried out with liquid loads (L) ranging between 6,370 and 31,850 kilograms per sq.metre per hour, and gas loads (G) ranging between 330 and 2,320 kilograms per sq.metre per hour. The liquid/gas ratio varied between 4 and 48.

By starting the experiments, the liquid and gas feed rates and the sulphur dioxide concentration of the entering gas was adjusted (approx. 4 and 5 vol.% sulphur dioxide). It was found that after five or ten minutes, the column reached the steady state. At the sampling, careful attention was paid to the running of the column. The analysis of the inlet gas gave uncertain results, therefore these concentration data were computed on the basis of the over-all mass balance of the column.

Among the others, two runs were selected, the concentration data of the phases measured during these runs are collated in Table 1. The data represent the sulphur dioxide concentration of the liquid phase, c_L (moles per litre) and that of the gas phase c_G, (volume per cent) along the packed height of the column and at a given liquid and gas load. Table 1. presents the concentration data of the phases in dimensionless form (x_L and y_G). The dimensionless concentration (y_G) was obtained by dividing the actual gas concentration with the same one of the inlet gas. In the case of the liquid, the dimensionless concentration was computed by the equilibrium equation, using the appropriate gas concentration data. The dimensionless concentration data have values between zero and one.

Comments are to be made with regard to the values of c_G and y_G at $z=0$. The dimensionless concentration of the feed gas at the bottom of the column is equal to one. The data y_G ($z=0$) in Table 1. represent the concentration data of the gas being in the packed zone at $z=0$. These concentration data cannot be determined experi-

Table 1. Experimental data

	Run N° 2.				Run N° 55.			
	L = 12,740 ; G = 990				L = 25,480 ; G = 1990			
z (-)	c_L (moles/litre)	c_G (vol.%)	x_L (-)	y_G (-)	c_L (moles/litre)	c_G (vol.%)	x_L (-)	y_G (-)
0.0	0.113	4.63	0.794	0.994	0.083	3.88	0.733	0.976
0.1	0.101	4.33	0.739	0.943	0.073	3.48	0.644	0.875
0.2	0.090	4.00	0.683	0.891	0.064	3.04	0.565	0.764
0.3	0.080	3.65	0.628	0.831	0.055	2.61	0.485	0.656
0.4	0.068	3.26	0.573	0.765	0.046	2.14	0.406	0.538
0.5	0.058	2.88	0.504	0.686	0.036	1.67	0.318	0.420
0.6	0.046	2.48	0.428	0.587	0.027	1.22	0.238	0.307
0.7	0.035	2.06	0.338	0.483	0.020	0.84	0.176	0.211
0.8	0.024	1.60	0.241	0.373	0.012	0.53	0.106	0.133
0.9	0.013	1.05	0.131	0.255	0.005	0.24	0.044	0.060
1.0	0.000	0.46	0.013	0.123	0.001	0.05	0.008	0.012

mentally, they were extrapolated using the concentration data measured at $z > 0$ heights. The results were $y_G(0) = 0.944$ and $y_G(0) = 0.976$, respectively. To increase the accuracy of the extrapolation, the sampling taps were located near to each other at the lower part of the column.

MATHEMATICAL MODELS FOR THE DESCRIPTION OF A PACKED ABSORPTION COLUMN

The dimensions of the Raschig rings are relatively small related to the dimensions of the column. The liquid, streaming downwards through the packings is dispersed into small droplets and films, and the number of these is high. Due to this, both the continuous and dispersed phases are described by a continuous mathematical model.In the examined case, this means that the properties of the phases are regarded as a continuous function along the height of the column. Among the others, two models are frequently used for the description of process units, these are the ideal Piston Flow (PF) model and the Axial-Dispersed Plug-Flow (ADPF) model.

It is presumed by the application of the PF model that the flow rate of the phase is independent along the path and the conductivity factor is zero.

According to these, the PF model can be formulated as follows:

$$\frac{\partial \Gamma}{\partial t} = - v \frac{\partial \Gamma}{\partial z} + \varepsilon \omega \Delta \Gamma \qquad (2)$$

Compared to the general equation used for the description of process units,Eq. (2) is simplified in two points. On the one hand the conductivity term is neglected,on the other it is assumed that the convective flux exist only in the direction of the z co-ordinate.

The most simple ADPF model assumes a conductivity flux along the z co-ordinate and the conductivity factor is independent along the path:

$$\frac{\partial \Gamma}{\partial t} = - v \frac{\partial \Gamma}{\partial z} + D \frac{\partial^2 \Gamma}{\partial z^2} + \varepsilon \omega \Delta \Gamma \qquad (3)$$

These two models will be used for the description of the packed column.

For the description of the two phase countercurrent absorption column, the following differential equation can be given based on the ideal PF model:

$$\frac{dx_i}{dz} + St_L[A(y_i - 1) + (1 - x_i)] = 0 \qquad (4)$$

$$\frac{dy_i}{dz} + St_G[A(y_i - 1) + (1 - x)] = 0 \qquad (5)$$

where

$$St_L = \frac{(\beta\omega)_i Z}{v_L} \; ; \; St_G = \frac{(\beta\omega)_i Z \; H}{v_G A} \; ; \; A = \frac{H \; c_{G,in}}{H \; c_{G,in} + c_o^*}$$

The differential equations of the ADPF model are:

$$\frac{1}{Pe_L} \frac{d^2 x_D}{dz^2} + \frac{d \; x_D}{dz} + St_L[A(y_D - 1) + (1 - x_D)] = 0 \qquad (6)$$

$$\frac{1}{Pe_G} \frac{d^2 y_D}{dz^2} - \frac{d \; y_D}{dz} - St_G[A(y_D - 1) + (1 - x_D)] = 0 \qquad (7)$$

where

$$Pe_L = \frac{v_L \; Z}{D_L H_L} \; ; \; Pe_G = \frac{v_G \; Z}{D_G H_G}$$

Eq. (4) and (5), as well as (6) and (7), describe the process unit only with the help of boundary conditions. These equations express the conservation law. For the evaluation of the boundary conditions, the mass balances to be constructed are valid at the contact points (z=0 and z=1). Several authors dealt with the problems of the boundary conditions [5, 6, 7], their work was used here, therefore a description of the details has been omitted Taking the PF model, the concentration of the gas in the packing at z=0 is to that of the inlet gas. Similarly, this is the case with the liquid at the opposite end of the packing (z=1), its concentration equals the inlet liquid. These are indicated in the following expression:

$$y_i(z=0) = 1 \tag{8}$$

$$x_i(z=1) = x_{in} \tag{9}$$

For an evaluation of the boundary conditions valid for the ADPF model, the absorption column as a whole has to be examined. The packed part of the column was regarded as a closed system and it was assumed that the properties of both the liquid and gas phases in contact with each other in the packed space are similar to the ideal plug flow. With these assumptions the boundary conditions are:

$$\left.\frac{dx_D}{dz}\right|_{z=0} = 0 \tag{10}$$

$$\left.\frac{dy_D}{dz}\right|_{z=0} + Pe_G[1 - y_D(z=0)] = 0 \tag{11}$$

$$\left.\frac{dy_D}{dz}\right|_{z=1} = 0 \tag{12}$$

$$\left.\frac{dx_D}{dz}\right|_{z=1} + Pe_L[x(z=1) - x_{in}] = 0 \tag{13}$$

The boundary conditions of the ADPF model give the concentration of the phases in the column that can be described with a continuous function, but a discontinuous function described the concentration values at the inlet points.

The differential equations of the models using the boundary conditions were solved [5, 8, 9]. E.g. the solution of Eq. (4) and (5), using the boundary conditions given in Eq. (8) and (9), is as follows:

when $\frac{A\ St_G}{St_L} \neq 1$

$$x_i = \frac{1 - x_{in}}{\frac{A\ St_G}{St_L} - \exp(St_L - A\ St_G)} \left\{\exp[(St_L - A\ St_G)z] - \frac{A\ St_G}{St_L}\right\} + 1 \tag{14}$$

$$y_i = \frac{St_G}{St_L} \frac{1 - x_{in}}{\frac{A\ St_G}{St_L} - \exp(St_L - A\ St_G)} \left\{\exp[(St_L - A\ St_G)z] - 1\right\} + 1 \tag{15}$$

MIYAUCHI and VERMEULEN [8] solved the equations of the ADPF model for several conditions, these can be found in their paper. The mentioned solutions were applied in the further calculations which were carried out by an electronic computer, Typ. ODRA 1204.

THE EVALUATION OF DATA ON THE BASIS OF THE APPLIED MODELS

First of all the parameters of the equations have to be determined. Knowing the numerical values of the parameters, the solution of the differential equation system presents the x(z) and y(z) functions. Comparing the measured and calculated concentration profile data, the applicability of the models used can be checked. At first the PF model was investigated.

The Determination of the Mass Transfer Coefficient of the PF Model

Being in the possession of the experimental data, the boundary conditions of the PF model enable a computation to be carried out for all the investigated sections of the column. The feature of the column is constant along its longitudinal axis, the used model involves this statement, therefore the concentration data $x_L(z)$ and $y_G(z)$ determined at the point z can be used for the calculation of the transfer coefficient $(\beta\omega)_i$ being valid for the examined volume unit of the column. The calculations can be carried out with the following expressions:

if $z > 0$ and $\Lambda \neq 1$

$$\beta\omega(z)_i = \frac{v_L}{zZ}\,\frac{1}{1-\Lambda}\ln\frac{\Lambda\{[1 - x_L(z)] + A[y_G(z) - 1]\}}{\Lambda[1 - x_L(z)] + A[y_G(z) - 1]} \qquad (16)$$

if $z = 0$ and $\Lambda \neq 1$

$$\beta\omega(z)_i = \frac{v_L}{Z}\,\frac{1}{1-\Lambda}\ln\frac{1 - x_{in} + \Lambda[x_{in} - x_L(0)]}{1 - x_L(0)} \qquad (17)$$

where $\Lambda = \dfrac{A\ St_G}{St_L}$

Using the measured concentration data of the previously mentioned two runs, the $(\beta\omega)_i$ value were computed and these are presented in Tables 2. and 3.

The values in the Tables 2. and 3. indicate that $(\beta\omega)_i$ is the function of the co-ordinate z, its mean value can be given by Eq. (18):

$$(\overline{\beta\omega})_i = \int_0^1 \beta\omega(z)_i\,dz \qquad (18)$$

The mean values are also presented in Tables 2. and 3.

The deviation of the $(\beta\omega)_i$ values from the average can be given by Eq. (19):

$$h = \frac{1}{(\overline{\beta\omega})_i}\int_0^1 \left|\beta\omega(z)_i - (\overline{\beta\omega})_i\right|\,dz \cdot 100, \quad \% \qquad (19)$$

Table 2. Calculated from the Data of Run 2.

PF model				ADPF model	
$(\overline{\beta\omega})_i = 7.08\text{x}10^{-3}$; $h = 14.5$ %; $\Delta c_i = 0.055$				$D_L=1.92\text{x}10^{-3} m^2 sec^{-1}$; $D_G=3.32\text{x}10^{-3}\ m^2 sec^{-1}$ $(\overline{\beta\omega})_D=8.48\text{x}10^{-3}\ sec^{-1}$; $St_L=5.10$; $St_G=5.30$; $\Delta c_D=2.68\text{x}10^{-2}$	
z	x_1	y_i	$(\beta\omega)_i \cdot 10^3$	x_D	y_D
0.0	0.797	1.000	8.16	0.800	0.995
0.1	0.711	0.905	9.95	0.736	0.897
0.2	0.627	0.811	7.45	0.652	0.804
0.3	0.544	0.719	6.65	0.569	0.712
0.4	0.462	0.629	6.34	0.487	0.622
0.5	0.382	0.540	6.06	0.406	0.533
0.6	0.303	0.452	5.82	0.327	0.446
0.7	0.225	0.366	5.86	0.249	0.360
0.8	0.149	0.282	6.11	0.172	0.275
0.9	0.073	0.199	7.12	0.096	0.192
1.0	0.000	0.117	8.38	0.022	0.113

Table 3. Calculated from the Data of Run 52.

PF model				ADPF model	
$(\beta\omega)_i = 5.63\text{x}10^{-3}\text{sec}^{-1}$; h=21.9 %; $\Delta c_i = 0.074$				$D_L=1.92\text{x}10^{-3}\text{m}^2\text{sec}^{-1}$; $D_G=4.68\text{x}10^{-3}\text{m}^2\text{sec}^{-1}$; $(\beta\omega) = 12.2\text{x}10^{-3}\text{sec}^{-1}$; $St_L=7.35$; $St_G=5.7$; $\Delta c_D= 0.046$	
z	x_i	y_i	$(\beta\omega)_i \cdot 10^3$	x_D	y_D
0.0	0.835	1.000	6.05	0.925	0.998
0.1	0.776	0.952	7.06	0.890	0.957
0.2	0.714	0.899	4.55	0.838	0.911
0.3	0.646	0.843	3.97	0.778	0.860
0.4	0.573	0.983	3.79	0.710	0.801
0.5	0.494	0.718	4.00	0.633	0.734
0.6	0.410	0.648	5.05	0.544	0.657
0.7	0.319	0.573	6.52	0.443	0.570
0.8	0.220	0.491	7.77	0.328	0.471
0.9	0.114	0.404	6.74	0.197	0.357
1.0	0.000	0.309	6.46	0.047	0.234

The equation of the model was solved using the mean $(\overline{\beta\omega})_i$ value and the sulphur dioxide concentrations of the liquid and gas phases were calculated. The computed $x(z)_i$ and $y(z)_i$ values are summarized in Tables 2. and 3. Comparing the x_L and y_G data in Table 1. with the adequate data in Tables 2. and 3., the discrepancies are significant to the model. The deviations between the data can be characterized by the following equation:

$$\Delta c_i = \frac{1}{2} \int_o^1 [|x_L - x_i| + |y_G - y_i|] \, dz \tag{20}$$

The Determination of the Transfer Coefficient of the ADPF Model

Using this model, not only is the transfer coefficient, or the St number unknown, but also the values of the other parameters, the mixing coefficients of the phases (D_L and D_G) are concealed. The mixing coefficients are included in Peclet numbers Pe_L and Pe_G. For the determination of the numerical values empirical formulas were published in literature [10, 11]:

$$\frac{v_G d_p}{D_G} = 2.4(Re_G)^{-0.2} \cdot 10^{-0.013-0.088 \frac{d_p}{d_k} Re_L} \tag{21}$$

$$\frac{D_L \rho_L}{\mu_L} = 0.527 \, (Re_L)^{1/2} (Ga_L)^{1/2} \tag{22}$$

$$Re_L = \frac{v_L d_p \rho_L}{\mu_L} \; ; \; Re_G = \frac{v_G d_p \rho_G}{\mu_G} \; ; \; Ga_L = \frac{d_p^3 g \rho_L^2}{\mu_L}$$

where d_k = diameter of the column (metre)

d_p = nominal diameter of the packing (metre)

ρ_L, ρ_G = liquid or gas density (kilograms per cu.metre)

μ_L, μ_G = dynamic viscosity of the liquid or gas (kilograms per metre per second)

g = gravitational constant (metres per sq.second)

The hold-up of the column was calculated by Eq. (23) [12]:

$$H_L = 3.48 \times 10^{-3} \left(\frac{v_L \rho_L}{d_p}\right)^{0.6} \tag{23}$$

The numerical values of constants in Eq. (23) were taken from literature [13].

The calculated mixing coefficients are presented in Tables 2. and 3.

For the determination of the $(\beta\omega)_D$ values, the experimentally determined data were used. The previously discussed boundary conditions of the ADPF model are valid only for the closed system and as such, the absorption column has to be regarded as a whole. Therefore it is impossible to calculate the $(\beta\omega)_D$ values for each section, there is only one $(\beta\omega)_D$ value for the whole column. Using the solutions of Eq. (6) and (7), the $(\beta\omega)_D$ value was determined in such a way that Eq. (24) is at minimum:

$$\Delta c_D = \frac{1}{2} \int_0^1 [\,|x_L - x_D| + |y_G - y_D|\,]dz \tag{24}$$

The calculated $(\beta\omega)_D$ values, and the $x(z)_D$ and $y(z)_D$ data are collected in Tables 2. and 3.

Δc_D is characteristic for the deviations between the calculated and measured values, this is also shown in the mentioned Tables.

THE VALUATION OF THE INVESTIGATED MODELS

The P.F. Model

The computed $(\beta\omega)_i$ values depend on z; it is caused either by the deficiency of the model or by the scattering of the measured data. For the determination of the scattering, several parallel runs were made. It was found that the scattering was $c_{\text{measurement}} =$

= 0.03. In contrast to this, in the experiments the following data were measured which are summarized in Table 4.

Table 4

$L < 12\,740$	$h \approx 31\ \%$	$\Delta c_i \approx 0.10$
$L \geq 12\,740$ $G < 990$	$h \approx 19\ \%$	$\Delta c_i \approx 0.05$
$L \geq 12\,740$ $G \geq 990$	$h \approx 14\ \%$	$\Delta c_i \approx 0.04$

The data show that the deviation Δc_i is many times higher than the experimental error. The two values approach each other if the liquid load of the column is high. It is assumed that the differences between the measured and calculated concentration values can be deduced both on the inadequacy of the model and experimental errors. The deviation is regarded as the sum of both:

$$\Delta c_i = \Delta c_{measurement} + \Delta c_{model}$$

From the data collected in Table 4., the conclusion can be drawn that if the liquid load is low, the model describes the investigated system imperfectly, here the value of Δc_{model} is approx. 0.07, which means a ten or fifteen per cent deviation between the measured and calculated concentration data. If the liquid load is increased, this deviation lessens in the examined range and finaly reaches the 0.01 value.

On the basis of this, it can be stated that by high liquid loads the PF model can be applied for the design of an absorption column. This statement is also supported by the values of h, which represent the deviations between the $\beta\omega(z)_i$ and the average. If the liquid load is low, the deviation of the $(\beta\omega)_i$ calculated from the experimental results, is 31 per cent, in the higher liquid load range this decreases until 14 per cent. The data suggest that

Table 5

B_L $\left(\frac{\text{litres}}{\text{hour}}\right)$	B_G $\left(\frac{\text{litres}}{\text{hour}}\right)$	$(\beta\omega)_D$ $(10^3/\text{sec})$	Δc_D (-)	$\frac{(\beta\omega)_D-(\overline{\beta\omega})_i}{(\beta\omega)_D}$ (%)	$\Delta c_i-\Delta c_D$ (-)	$\Delta c_{mod,D}$
50	2000	2.99	0.048	-37.4	0.045	0.018
	4000	6.58	0.048	48.8	0.035	0.018
	6000	5.82	0.033	37.8	0.032	0.003
	8000	5.85	0.033	61.7	0.082	0.003
	10000	5.60	0.043	64.2	0.076	0.013
100	2000	6.04	0.027	39.8	0.027	0.000
	4000	10.30	0.024	28.8	-0.003	0.000
	6000	9.19	0.023	26.5	0.032	0.000
	8000	11.38	0.033	41.5	0.022	0.003
	10000	11.06	0.029	47.8	0.046	0.000
150	4000	13.00	0.046	53.5	0.034	0.016
	6000	13.18	0.027	24.2	0.001	0.000
	8000	11.32	0.019	1.2	0.008	0.000
	10000	14.56	0.032	23.6	0.007	0.002
	12000	16.27	0.023	46.2	0.042	0.000
	14000	15.17	0.036	45.9	0.024	0.006
200	4000	16.23	0.039	58.6	0.031	0.009
	6000	25.50	0.040	58.8	0.016	0.010
	8000	17.92	0.026	29.4	0.014	0.000
	10000	16.84	0.024	11.2	0.001	0.000
	12000	17.44	0.044	22.3	-0.001	0.014
	13000	17.95	0.046	24.3	0.010	0.016
	14000	19.79	0.027	49.8	-0.009	0.000
250	4000	18.81	0.045	64.9	0.028	0.015
	8000	18.40	0.031	31.9	0.014	0.001
	10000	20.80	0.024	21.9	-0.001	0.000
	11000	16.10	0.042	25.5	-0.012	0.012

with low liquid and gas loads, the PF model is inapplicable either in the project work or in the qualification of a running absorption column.

The ADPF Model

The Δc_D values, characteristic for the deviations between the measured and calculated concentration data, are collected in Tables 2. and 3. Table 5. includes all the measured data, these show that the deviation caused by the application of the ADPF model was not higher than 0.01 in all the cases if $\Delta c_{measured} = 0.03$ is assumed. The mean of the $\Delta c_{measured}$ values is approx. 0.007. Therefore it can be stated that the ADPF model is suitable, between the investigated limits, for the description of the absorption column.

The appropriate $(\beta\omega)$ values calculated either on the basis of the PF, or ADPF models do not agree numerically with each other. The $(\beta\omega)$ values presented by the ADPF model are higher (Table 5.), this can be attributed to the mixing phenomena which decrease the efficiency of the column. The data show that the transfer coefficients related to the unit volume of the packing were ten or sixty per cent higher of the ADPF model was selected as the basis of the calculations instead of the PF model.

The deviations between the above discussed data reveals the fact that care must be taken by the application of the data published in literature. It is always recommended to check the mathematical model in which the calculations are based.

USED SYMBOLS

c_L^* equilibrium concentration in the liquid phase (moles per litre)

H	equilibrium constant (dimensionless)
c_o^*	intercept of equilibrium straight line (moles per litre)
c_G	concentration in the gas phase (moles per litre)
c_L	concentration in the liquid phase (moles per litre)
L	liquid load (kilograms per sq.metre per hour)
G	gas load (kilograms per sq.metre per hour)
B	feed (litres per hour)
x	dimensionless concentration of the liquid phase
y	dimensionless concentration of the gas phase
Γ	density (mass per cu.metre)
t	time (sec)
z	co-ordinate
ε	general transfer factor (metres per second)
ω	specific surface (sq.metres per cu.metre)
D	mixing factor (sq.metres per second)
St	Stanton number (dimensionless)
β	mass transfer coefficient (metres per second)
Z	length of the packed column (metres)
v	velocity (metres per second)
H_L	hold up (dimensionless)
h	deviation from average (per cent)
Δc	mean deviation of the measured and calculated concentrations

Indexes

L	liquid phase
G	gas phase
in	inlet

i piston flow model

D axial-dispersed plug-flow model

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РЕЗЮМЕ

Целью авторов являлось многостороннее изучение вопросов,возникщих при математическом моделировании насадочных абсорбционных установок.

В работе описан экспериментальный метод, применимый к измерению распределения концентрации складывающегося в насадочной колонне. Полученные измерения были обработаны на основе модели так называемого идеального вытеснения и диффузионной модели, содержащей также и осевое перемешивание.Сопоставление измерных распределений концентрации с вычисленными датами показало, что действительные условия при обстоятельствах опита во всей области описаны диффузионной моделью достаточной точностью. Модель идеального вытеснения является подходящей при более интенсивном режиме работы. Коэффициент передачи компонента был определен на основе обеих моделей.При этом с помощью диффузионной модели были получены значения ($\beta\omega$) примерно на 20 - 60 % выше,чем при помощи модели идеального вытеснения.