

where the $P_k(x_1)$ are defined as follows:

$$P_0(x_1) = 1$$

$$P_1(x_1) = (x_1 - a_1)P_0(x_1)$$

$$P_{k+1}(x_1) = (x_1 - a_{k+1})P_k(x_1) - b_k P_{k-1}(x_1) \quad k > 1 \quad (8)$$

The parameters a_k and b_k are evaluated so as to generate the set of orthogonal polynomials $P_k(x_1)$ from the complete experimental data set. After the evaluation of these coefficients, the c_k are calculated for a least-squares method. The polynomial expansion obtained in this way allows the integration of the function $(G^E/RT)^{\text{exp}}$ according to eq 2 or the application of the method proposed by Apelblat and Wisniak, using the entire composition range. The constants A_{ij} are obtained from the resolution of the following system of equations:

$$f^{\text{Wilson}}(A_{12}, A_{21}, x_1=0.5) = f^{\text{exp}}(A_{12}, A_{21}, x_1=0.5) \quad (9)$$

$$f^{\text{Wilson}}(A_{12}, A_{21}, x_1=1) = f^{\text{exp}}(A_{12}, A_{21}, x_1=1) \quad (10)$$

which was solved by the Newton-Raphson method.

Results and Discussion

The proposed method was applied to different isothermic systems. The expansion equation 8 allows also the application of Apelblat and Wisniak method. The results obtained by computer calculations are shown in Table I. The correlation ability of the Wilson constants evaluated by the two processes described above and of those given by Hirata et al. (1976) was calculated by the following error function:

$$E_\gamma = \left\{ \sum_{i=1}^n |\gamma_{1i}^{\text{cal}} - \gamma_{1i}^{\text{exp}}| / \gamma_{1i}^{\text{exp}} + |\gamma_{2i}^{\text{cal}} - \gamma_{2i}^{\text{exp}}| / \gamma_{2i}^{\text{exp}} \right\} / n \quad (11)$$

From the analysis of Table I, it can be inferred that the accuracy of the proposed method is at least as good as the other methods. On the other hand, the obtained constants A_{ij} are consistent with the complete experimental data set.

Finally, it should be mentioned that the method is in principle applicable to any equation for the excess Gibbs energy correlation, though conditioned to the intrinsic fitting capability of such an equation.

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CORRESPONDENCE

Comments on "Tuning Controllers on Distillation Columns with the Distillate-Bottoms Structure"

Sir: A recent paper by Papastathopoulou and Luyben (1990) discusses modeling and controller tuning of distillation columns using the DB scheme. We would like to point out that their main result, which is to show how models for the DB scheme may be derived from more conventional control structures provided the liquid flow dynamics are included, is taken from the work of Skogestad and co-workers (1989a,b, 1990a,b).

There are also two misconceptions in their paper that deserve comments.

1. In the Introduction they claim that for the case of perfect level control the DB scheme is equivalent to the RR-BR scheme (also denoted the $L/D-V/B$ configuration; i.e., using reflux ratio to control top composition and boilup ratio to control bottom composition). However, as shown by Skogestad et al. (1990a), these configurations behave entirely differently even when level control is perfect. For example, while the DB scheme works only when both loops are closed, the $(L/D)(V/B)$ configuration performs reasonably well even when both loops are in manual.

2. The transfer function $1/(1 - g_L)$ in eq 24 contains a pure integrator. This was shown previously by Skogestad

and co-workers (1989b, 1990b). In eq 29 Papastathopoulou and Luyben (1990) derive an expression for $1/(1 - g_L)$, which contains the integrator, but which is otherwise incorrect (except for the case with only one tray, i.e., $N_T = 1$).

Nomenclature

- B = bottoms flow rate
 D = distillate flow rate
 $g_L(s)$ = transfer function for liquid lag through column
 L = reflux flow rate
 L/D = RR = reflux ratio in top
 N_T = number of trays in column
 V = boilup flow rate
 V/B = RB = "reflux" ratio in bottom

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- Papastathopoulou, H. S.; Luyben, W. L. Tuning Controllers on Distillation Columns with the Distillate-Bottoms Structure. *Ind. Eng. Chem. Res.* 1990, 29, 1859–1868.

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Response to Comments on "Tuning Controllers on Distillation Columns with the Distillate-Bottoms Structure"

Sir: We are happy to acknowledge that we were introduced to the idea for using dynamic transformations during a seminar that Professor Skogestad presented at Lehigh University in June 1989 where he talked about using them to calculate frequency-dependent relative gain arrays. We attempted to acknowledge this in our paper by citing his paper (Skogestad et al., 1990). We then applied his approach in order to tune the controllers in the distillate-bottoms (D-B) structure and extended it to a sidestream column process.

We do not agree with the statement that the D-B and RR-BR (reflux ratio-boilup ratio) schemes behave entirely differently. It is certainly true that they behave differently if only one of the loops is on automatic or if a constraint has been hit. But when both are operational, our experience has been that their performances are essentially the same.

We thank Skogestad et al. for pointing out that eqs 26-29 in our paper contain an algebraic error.

Literature Cited

- Skogestad, S.; Jacobsen, E. W.; Morari, M. Inadequacy of Steady-State Analysis for Feedback Control: Distillate-Bottoms Control of Distillation Columns. *Ind. Eng. Chem. Res.* 1990, 29, 2339-2346.

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