identified, as is true in many staged operations, there is little incentive to use a transfer matrix model for control system design. A variety of methods are available for the state vector model. These include uncoupling approaches such as structural-analysis (Greenfield and Ward, 1967) and state variable feedback (Falb and Wolovich, 1967), as well as optimal control synthesis (Schuldt and Smith, 1971) and modal approaches (Changlai et al., 1973).

NOTATION

D = decoupling matrix
d = decoupling matrix element
G = process transfer matrix
g = process transfer matrix element
M = matrix defined in Figure 7
m = pseudo-input vector
P = diagonal feedback control matrix
p = feedback control matrix element
r = setpoint vector (see v definition below)
T = matrix product GD
u = process input vector
v = process disturbance vector (This symbol is used to represent either a disturbance or setpoint input in signal flow graphs.)
y = process output vector

LITERATURE CITED

Bollinger, R. E., and D. E. Lamb, "The Design of a Combined Feedforward Feedback Control System," *Chem. Eng. Progr. No. 66*, **61**, 55 (1965).

Changlai, Y. S., and T. J. Ward, "Decoupling Control of a Distillation Column," *AIChE J.*, **18**, 225 (1972).

Changlai, Y. S., G. G. Greenfield, and T. J. Ward, "Structural-Modal Process Control," *Proc. 1973 Joint Automatic Control Conf.*, 544, IEEE, New York (1973).

Falb, P. L., and W. A. Wolovich, "Decoupling in the Design and Synthesis of Multivariable Control Systems," *IEEE Trans. Auto. Contr.*, **AC-12**, 6, 651 (1967).

Freeman, H., "A Synthesis Method for Multipole Control Systems," *AIEE Trans. Appl. Ind.*, **76**, 28 (1957).

Greenfield, G. C., and T. J. Ward, "Structural Analysis For Multi-variable Process Control," *Ind. Eng. Chem. Fundamentals*, **6**, 564 (1967).

———— "Feedforward and Dynamic Uncoupling Control of Linear Multivariable Systems," *AIChE J.*, **14**, 783 (1968).

Kavanagh, R. J., Noninteracting Controls in Linear Multivariable Systems," *AIEE Trans. Appl. Ind.*, **77**, 425 (1958).

Luyben, W. L., "Distillation Decoupling," *AIChE J.*, **16**, 198 (1970).

Mesarovic, M., *The Control of Multivariable Systems*, MIT Press, Cambridge (1960).

Rosenbrock, H. H., "The Distinctive Problems of Process Control," *Chem. Eng. Progr.*, **58**, 43 (1962).

————, "Design of Multivariable Control Systems Using the Inverse Nyquist Array," *Proc. IEE*, **116**, 11, 1929 (1969).

Schuldt, S. B., and F. B. Smith, Jr., "An Application of Quadratic Performance Synthesis Techniques To a Fluid Cat Cracker," *Proc. 1971 Joint Automatic Control Conf.*, 270, IEEE, New York (1971).

Waller, K. V. T., "Decoupling In Distillation," *AIChE J.*, **20**, 592 (1974).

Zalkind, C. S., "Practical Approach to Non-Interacting Control," *Instr. Control Systems*, **40**, 89, 111 (1967).

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Reply

KURT V. T. WALLER

Department of Chemical Engineering
Abo Akademi, Abo, Finland

The above note by Yang and Ward is essentially an extract from a previous note by Changlai and Ward (see Literature Cited above). The control strategy labeled *decoupling* by Changlai and Ward is labeled *pseudo-decoupling* by Yang and Ward, who expect this change of nomenclature to lead to difficulties in the implementation of the control. I don't.

The main point in the note by Yang and Ward is that in distillation *V*-structure design is to be preferred to *P*-structure design. Rijnsdorp (1965) has come to the opposite conclusion. I join Rijnsdorp and to his motives I would like to add the following:

One very serious drawback of connecting the decouplers according to the *V*-scheme of Changlai and Ward is that they easily may turn out to be unrealizable, in distillation probably more often than not. In the experimental example discussed in my note, for instance, the *V*-decouplers are unrealizable since they have to contain negative dead time. This is a consequence of the fact that they have been so unsuitably connected that dead time in the process has to be compensated by negative dead time in the decouplers. This drawback is far too great to be compensated by the advantage that only two decouplers are needed (for systems with two inputs and two outputs). Another drawback of the *V*-design, in line with the argumentation of Yang and Ward, is that the design results in only one out of the infinite number of possible decoupling schemes and that nothing guarantees that this special choice is more effective than other choices.

The four simple schemes discussed in my note, Equations (4) to (7), also need only two decouplers (for two input-two output systems). But besides providing straightforward and simple design, they have the advantage of being related in such a way that at least one of the schemes is realizable with good approximation in practically all cases.

Yang and Ward consider the lack of uniqueness in *P*-structure design a weakness. The example discussed above illustrates that freedom in design is a strength and not a weakness.

What is left in the above note by Yang and Ward—besides some self-evident explanations of simple facts in my note—is the statement that there are several other design methods than decoupling for multivariable control systems. With this I completely agree.

LITERATURE CITED

Rijnsdorp, J. E., "Interaction in Two-Variable Control Systems for Distillation Columns—I. Theory," *Automatica*, 3, 15 (1965).