LETTERS TO THE EDITOR

To the Editor:

PERCEPTIONS OF THE STATE OF PROCESS CONTROL

Chemical process control is a controversial field today. Many practitioners believe that control system design is a mature process, in which classical techniques and designer experience will always lead to a satisfactory and perhaps optimal system. Many university researchers believe that the advances in control theory during the past two decades, advances motivated largely by aerospace problems, can be applied with great profit to the problems of the process industries. Publications by members of these groups have done little to establish a satisfactory dialogue; few practitioners have more than a superficial knowledge of modern control theory, and modern control researchers have produced few convincing examples of successful applications.

An intensive, week-long conference devoted to an assessment of the present status and needs of chemical process control was held at Asilomar Conference Grounds, Pacific Grove, California, from January 18-23, 1976, organized by the Engineering Foundation, with cosponsorship by the AIChE and the Control Systems Society, Inc., of the IEEE and with financial support from the National Science Foundation. Half of the approximately eighty participants were from industry and half from universities, all with a wide range of ages and experience and with backgrounds in chemical, electrical, and control engineering. Nine participants were from Britain and Europe. The discussion, which was free and open, was motivated in part by prepared evaluations which had been distributed in advance of the conference, and by week's end a reasonably clear picture had emerged. Conference papers and summaries of discussion will be published in AIChE Symposium Series No. 159, Volume 72. The purpose of this brief note is to record our personal observations for the wider chemical engineering community. We have particularly in mind those engineers in industry and education who are not active in the process control field but who must evaluate the relevance of research and new technology.

First, it is evident that much of the present confusion regarding the applicability of modern control theory is simply a consequence of problems of communication and problem definition. It is certainly true that most process control problems can be solved satisfactorily by classical means and that difficult control problems can sometimes be avoided or overcome by process changes. These are not the problems that modern control methods are intended to solve, and to apply advanced methods to such problems is inappropriate.

There are, however, process control problems that require advanced techniques. Such problems are well known and documented in the paper, cement, and metal processing industries, where the large capital outlay and repeat designs of process equipment can easily justify large expenditures on process control equipment and algorithms. Advanced control techniques have been applied successfully in the chemical process industries as well, although the applications and results have not been adequately documented in the open literature. This traditional secretiveness of the chemical process industries, which has resulted in a distorted picture of the relevance of process control research, poses the real danger of encouraging an exodus of academics from the process control field at a time when the need for chemical engineers with process control training is likely to grow.

Modern control methods have failed to gain acceptability at least in part because of a misunderstanding of what should be expected from them. Research papers often imply that the methods are *algorithmic*, in that they will yield the detailed design of a control system. This is not the case in fact. All that should be expected of any control design method is that it will provide insight into the *structure* of the control system; detailed design requires interaction in a closed loop with an engineer who is familiar with the process. There is a clear educational need here to ensure that modern methods will become a part of the process control engineer's "bag of tricks" and that he will be given the opportunity to hone his skill in the art of their application. That charge is considerably more demanding than is the traditional first course in process control because of the complexity of the topic and the higher level of mathematical knowledge required.

A primary need at present is a set of industrywide case studies which can be used to evaluate the utility of modern multivariable control techniques. Publication of more industrial case studies would do much to educate the profession about the spectrum of control problems and to clear away current misunderstandings that arise from differences in vocabulary. There are such examples which could be published without affecting proprietary positions in any way. In such publications we would ask for high standards of reporting. There must be incisive articulation of the fundamental problems. The fundamental keys to success and the gremlins of failure must be communicated; otherwise we shall continue to have little more than superficial story telling and ostentatious name dropping. Continued reluctance of the chemical process industries to share in this part of the educational process will assuredly stunt the development of this field and could lead to a future situation in which engineers with needed talents are not available.

It is essential that academic researchers have an opportunity to apply modern control system design methods to realistic processes, both for the training of students and for the evaluation of new techniques. Laboratory pilot plants have been used successfully, but the processes have been too simple to be convincing. There is still a need for testing the new control methods on actual physical laboratory processes, but such work is expensive and difficult. Another important dimension would be added if good dynamic simulations were made widely available, so that a common process model could be utilized by different groups. Simulations do exist which are considered to be accurate representations of the dynamics of important chemical and petrochemical processes, and they could provide test cases of control design methods, perhaps under conditions of time limitation. To be useful, researchers should have access to such simulations only in the form of manipulations of inputs and noise-distorted outputs. Access through a network like that developed by the CACHE Corporation for FLOWTRAN could provide the necessary availability and program security. Reliance on simulations should not be overemphasized, since the danger exists that design techniques will simply be used to exploit unrealistic model limits, rather than real phenomena, but this seems to us to be a feasible opportunity for establishing credible base cases.

This proposal is not without critics and a further danger. Critics would not trust such simulations in the evaluation of the operating performance of control systems; that has to be done, they argue, with real processes. The further danger, and it is a serious one, is that nationally published simulations might carry with them an implied endorsement by the profession that the processes simulated are "right" and involve control problems of central importance. It must be recognized that problems so presented are, to the user of the simulation, some other person's perception of the problems. Perceptions coming from one or a few minds are not enough in this complex field; we need the perceptions of many independent thinkers.

Practitioners at the conference showed a general concern with problems of instrument failure to a degree not previously appreciated by most academic participants. There are important unanswered questions regarding the effect of instrument failure on control systems designed by advanced methods. This is an important area of research for theorists interested in process control applications.

Persons interested in specific problems, techniques, and applications should consult the conference papers and summaries of discussion in the Symposium Series. The primary message which we wish to leave here is the conviction that chemical process control is an area in which important advances have been made, but they are not being absorbed into the culture of chemical engineering practice at a sufficiently rapid rate. As a result, many chemical engineers believe that modern tools are not needed or not applicable. Should this attitude continue to persist over a wide segment of the process industries, the growth of know-how lag behind the needs, and, more seriously, human resources will be in short supply. It is therefore important that chemical engineers evaluate anew the potential of this rapidly changing field.

ACKNOWLEDGMENT

These personal observations stem from five days of discussions, formal and informal, with all of the participants at the Engineering Foundation Conference on Chemical Process Control. We are particularly indebted to the Foundation staff and to the other four members of the conference committee—Harmon Ray, Dale Seborg, Vern Weekman, and Charles Wells. The financial support from the National Science Foundation was an important factor in the success of the conference.

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To the Editor:

The letter to the Editor from Dr. Shin-Seung Kim, *AIChE Journal*, **22**, 815 (1976), commenting on the article by Chandrasekhar and Hoelscher, *AIChE Journal*, **22**, 103 (1975), contains comments which were answered in our letter published in the January 1976 issue. In brief, the boundary conditions used in our paper are correct as printed; Equation (3) in the paper was misprinted, and we expressed gratitude to Huan and Winnick, *AIChE Journal*, **21**, 103 (1975), for calling the error to our attention.

The comment by Kim about the possibility of interfacial turbulence during our studies is simply not valid, revealing, I suggest, a lack of familiarity with the experimental technique which we used and described in our article. Any degree of interfacial turbulence would have made the photographs—the primary source of our data—unreadable. These photographs are available for scrutiny. True, Ward and Brooks likewise did not find interfacial disturbances.

We again suggest that the experimental techniques used prior to that which provided the basis for our work inferred conditions at the interface from measurements taken a great distance from that interface. Our work provided a much closer examination of the interface. The results from the use of the instrument described in our paper depend entirely on the photographic evidence obtained. This is not a common analytical tool in chemical engineering. We urge that other studies using this technique be made and that further comment on our conclusions vis-a-vis interfacial resistances then be offered.

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To the Editor:

EFFECT OF SURFACE TENSION ON SIEVE TRAY PRESSURE DROP

In "Prediction of the Pressure Drop Across Sieve Trays," *AIChE J*, **21**, 1218 (1975), Davy and Haselden describe a prediction method for the pressure drop across a sieve tray. In the paper they note that although "it was expected that surface tension would be a significant variable, . . . no trend has emerged." The reason for this is clear when the vapor volume flow rate per hole is considered in conjunction with the bubbling characteristics of the holes.

It has long been known that bubbles issuing from a submerged orifice behave in a quasi-static manner at low gas flow rates and in a dynamic manner at higher flow rates. In the former case, inertial forces are negligible and the bubble size at departure is given by (Van Krevelen and Hoptijaer, 1950):

$$V_b = k_1 \pi d_h \sigma / g \Delta\rho \qquad (1)$$

In the latter case, only inertial forces are important and V_b is given by (Walker and Davidson, 1963):

$$V_b = k_2 (\overline{Q}^2/g)^{3/5} \qquad (2)$$

It was shown by D'Arcy, (1975) that these two relations provide a lower bound to bubble sizes for a wide variety of experimental conditions. Suitable values of the constants are $k_1 = 1$, $k_2 = 0.8$. Accordingly, the bubbles are controlled by dynamic forces if $\overline{Q} > Q_c$ and by static forces if $\overline{Q} < Q_c$ where Q_c is the value of $\overline{Q}$ at the intersection of (1) and (2):

$$Q_c = \sqrt{g[(k_1/k_2)\pi d_h \sigma / g\Delta\rho]^{5/3}} \qquad (3)$$

Allowance must be made for (i) a small region about Q_c where static and dynamic forces are of comparable magnitude, and (ii) the volume of the gas chamber upstream of the orifice which has the effect of increasing Q_c somewhat.

Evaluating Q_c and $\overline{Q}$ for the experimental data quoted Davy and Haselden shows that in all cases $\overline{Q}$ is at least 8 times as large as Q_c. Even making allowance for the above effects, this indicates that static forces such as surface tension force were unimportant in all these experiments.

Even if the liquid hold up was such that either the bubbles reached the "surface" and burst prematurely, or the gas penetrated the liquid as a continuous jet, the momentum of the gas was adequate to overwhelm surface tension forces and hence no such effect was seen.

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