LETTERS TO THE EDITOR

To the Editor:

Myers (1985) and Sgheiza and Myers (1985) have performed a valuable function in adding their important voices to those questioning the long-held opinion that nucleation during nucleate boiling occurs only because of surface imperfections. In the first paper the hypothesis is advanced that microbubbles carried by the liquid, influence nucleation at the boiling surface. Two additional points are relevant to this hypothesis. The first is that the superheat in the liquid, just a short distance away from the surface, is much lower than at the surface. This is because a steep temperature gradient occurs in the liquid next to the surface. The second is that when a source of entrained vapor bubbles is brought very close to the surface, nucleate boiling is enhanced.

The work of Bobst and Colver (1968) illustrates the first point. They measured the temperature at distances close to a surface while boiling water at 1 atm. They report that at a heat flux of 28 kW/m^2 the surface temperature was close to 6 K superheated but only 0.5 mm into the liquid, the liquid was superheated less than 2 K. Their heat flux is close to the heat flux of 27 kW/m^2 in Raad's experiment which Myers cites. With less than 2 K of superheat, many smaller bubbles would shrink or collapse in travelling very far before reaching the high superheat at the surface.

One way to maximize the chances that entrained vapor bubbles reach the high superheat at the surface without losing as many smaller bubbles that might exist originally, is to locate the source of entrained bubbles as close to the surface as possible. This can be accomplished by boiling a film of liquid. Here, bubbles quickly grow larger than the film thickness and are liable to burst. These bursting bubbles produce many liquid drops and a number of these are driven back to strike the liquid surface where they can entrain vapor bubbles back into the main body of the liquid. Vortex rings formed by impact of the drops on the liquid surface can carry entrained bubbles (Carroll and Mesler, 1981). Drops from bursting bubbles have been demonstrated capable of causing nucleation in two special cases—a bubble bursting on the surface of a pool of carefully superheated water (Bergman and Mesler, 1981), and a bubble bursting from a film of boiling water (Mesler and Mailen, 1977). The entrainment of vapor bubbles by drops has been called secondary nucleation (Mesler, 1982).

The second point is supported by the several reports of the enhancement of nucleate boiling by reducing the depth of liquid covering the surface (Kim, et al., 1983; Marto, et al., 1977; Nishikawa, et al., 1967). While it has not been proven that entrainment of vapor bubbles is primarily responsible for the enhancement, the possibility certainly deserves further study. Whether more enhancement results directly from secondary nucleation or indirectly through activation of short-lived sites, as Myers proposes, needs to be studied.

Sgheiza and Myers have reported interesting new results of transient surface temperature measurements during nucleate boiling. The measurements were made by a noninvasive technique at high heat flux where direct observation of nucleation is difficult because the bubble population obscures the view. They have interpreted their results as experimental support for a hypothesis that circulating microbubbles influence nucleation during nucleate boiling. The results also provide a powerful and useful test of the secondary nucleation hypothesis.

Sgheiza and Myers in their discussion do not consider the origin of their microbubbles. The primary purpose of this note is to observe that their hypothesis of circulating microbubbles fits in sequentially with the secondary nucleation hypothesis.

At high heat flux where direct observations of nucleation are difficult, the experiments by Kirby and Westwater (1965) and Iida and Kobayasi (1970) have shown that escaping vapor pushes away the liquid on a boiling surface, leaving the surface wet intermittently with a liquid film. Bubbles bursting from the film would be especially conducive to secondary nucleation.

A secondary purpose of this note is to make a minor comment on the statement by Sgheiza and Myers that the microlayer did not dry out during any of their measurements with water. In describing the results of tests OC10WM14 and OC10WM17 they report observing a very small temperature drop during surface temperature recovery from the cooling caused by microlayer evaporation. Ordinarily this would be interpreted as an indication that the microlayer did dry out.

Literature cited

Bergman, T., and R. Mesler, "Bubble Nucleation Studies. I: Formation of Bubble Nuclei in Superheated Water by Bursting Bubbles," *AIChE J.*, **27**, 851 (1981).

Bobst, R. W., and C. P. Colver, "Temperature Profiles up to Burnout Adjacent to a Horizontal Heating Surface in Nucleate Boiling," *AIChE Symp. Ser.*, **64** (82), 26 (1968).

Carroll, K., and R. Mesler, "Bubble Nucleation Studies. II: Bubble Entrainment by Drop-Formed Vortex Rings," *AIChE J.*, **27**, 853 (1981).

Kim, H.-K., A. Fakeeha, and R. B. Mesler, "Nucleate Boiling in Flowing and Horizontal Liquid Films," *Interfacial Transport Phenomena*, ASME, **HTD-23**, 61 (1983).

Marto, P. J., D. K. MacKenzie, and A. D. Rivers, "Nucleate Boiling in Thin Liquid Films," *AIChE Symp. Ser.* **73** (164), 228 (1977).

Mesler, R., and G. Mailen, "Nucleate Boiling in Liquid Films," *AIChE J.*, **27**, 985 (1977).

Mes.er, R. B., "Research on Nucleate Boiling," *Chem. Eng. Educ.* **16**, 152 (Fall, 1982).

Myers, J. E., "Short-Lived Sites in Nucleate Boiling," *AIChE J.*, **31**, 1441 (1985).

Nishikawa, K., H. Kusuda, K. Yamasaki, and K. Tanaka, "Nucleate Boiling at Low Liquid Levels," *Bulletin JSME*, **10**, 328 (1967).

Sgheiza, J. E., and J. E. Myers, "Behavior of Nucleation Sites in Pool Boiling," *AIChE J.*, **31**, 1605, (1985).

Russell Mesler
Department of Chemical Engineering
University of Kansas
Lawrence, KS 66045

To the Editor:

Smith, Krieger, and Herzog, in studying wall reaction and transport effects in a fast reaction system, [*AIChE J.*, **26** (4), 567 (1980)], summarized the criteria for validity of the plug flow assumption. Their criteria are, however, inconsistent with those of Walker (1961).

Our study confirms Walker's work; i.e., the dimensionless homogeneous loss rate, α, is less important with respect to the validity of the plug flow model than the dimensionless wall reaction rate, H;

and this validity is independent of the dimensionless axial distance, λ, when velocity is extremely small. We believe that the conclusion made by Smith, et al. is partially due to an imperfection in the numerical algorithm (Poirier and Carr, 1971) which they used.

It is apparent that only the boundary condition at $u = 0$ forms the first finite difference equation and only the condition at $u = 1$ forms the last equation in Poirier and Carr's algorithm. The proper way to construct (by finite difference method) a set of simultaneous algebraic equations, is to incorporate boundary conditions, with respect to corresponding coordinates, into the governing equation (Lapidus, 1962) because the governing equation must be valid everywhere in the system considered.

Their neglect of homogeneous reaction on the boundaries in the radial direction underestimates the rate of species disappearance by homogeneous reaction. One therefore exaggerates the importance of α on deviation from the plug flow assumption. The wall reaction is confined to the wall and depends on radial dispersion for supply of reagents, while bulk reaction occurs everywhere in the reactor (including on the wall) and can sustain itself by depleting local molecules. Parabolic velocity profile retards wall reaction by creating a high concentration zone away from the wall, but it has less effect on bulk reaction because each stream line can be taken as a plug flow reactor.

The validity of the plug flow model also depends on λ, except under conditions such that radial dispersion competes with bulk velocity or with wall reaction, resulting in a radial concentration profile that is nearly uniform. The basic argument for inclusion is that conversion of the uniform radial concentration profile at the reactor entrance to a parabolic profile downstream must occur gradually, and the validity depends on how far the real profile is from its corresponding uniform profile.

We, therefore, conclude that the validity of the plug flow assumption depends on α, H, and λ and that H is a stronger factor than α upon its validity.

Literature cited

Lapidus, L., *Digital Computation for Chemical Engineers,* McGraw-Hill, New York, Ch. 4 (1962).

Poirier, R. W., and R. J. Carr, "The Use of Tubular Flow Reactor for Kinetic Studies over Extended Pressure Ranges," *J. Phys. Chem.,* **75** (10), 1593 (1971).

Walker, R. E., "Chemical Reaction and Diffusion in a Catalytic Reactor," *Phys. Fluid,* **4** (10), 1211 (1961).

S. H. Chang and J. W. Bozzelli
Department of Chemical Engineering and Chemistry
New Jersey Institute of Technology
Newark, NJ 07102

To the Editor:

We would like to call attention to the *AICHE J.* that the article by S. V. Alekseenko et al. entitled "Wave Formation on a Vertical Falling Liquid Film," **31**(9), 1446 (1985) is in large part similar in title and manuscript content with an article published by the same authors in *Int. J. Multiphase Flow,* **11**(5), 607 (1985).

Siu-Ming Yih
Professor and Chairman
Dept. of Chemical Engineering
Chung Yuan Christian University
Chung-Li, Taiwan, 320, China

Editor's Note:

Professor Yih is correct. The final versions of nearly identical papers were received by the two journals within one month of each other, even though the authors transferred the copyright of their paper to the *AIChE Journal* when the paper was accepted for publication.

Errata

In the paper "Automatic Synthesis of Optimum Heat Exchanger Network Configurations" by C. A. Floudas, A. R. Ciric and I. E. Grossmann (**32** (2), 276 (1986)), the authors incorrectly reported several results. The corrections are as follows: p. 285, right column, 2nd paragraph, line 6, "377,900" should read "373,900." p. 287, Table 10, the reported areas correspond to 11.1 K approach. The correct areas for 6.38 K are: 81.3 (H1-C1), 43.2 (H2-C1), 26.1 (H3-C1), 190.3 (H6-C1), 18.3 (H1-C1), 25.1 (H3-C1), 320.1 (H4-C1), 25.7 (H1-CW), 89.4 (H5-CW); the cost of the furnace is 2.5505 $Q^{0.7}$.