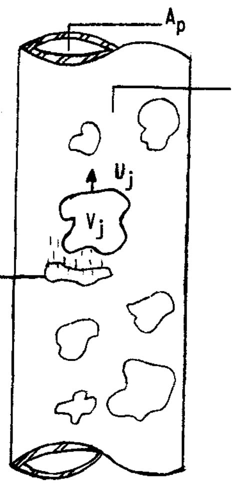

Fig. 1. Irregularly shaped bubbles in a pipe.

An idealized analysis indicates the effects of the bubble size distribution on the gas contact time and on the volumetric void fraction. For the purpose of illustration, the actual behavior of bubbles moving in a liquid is approximated by an infinite-medium solution. Influence of pipe wall on all aspects of bubble size and motion is neglected, bubbles are uniformly distributed across the area perpendicular to flow, and all bubbles of the same radius move at the same velocity. For these conditions, the average bubble chord pierced by the probe has a length of $(4/3)r$. The variance or standard deviation of the chord about the average is $(\sqrt{2}/3)r$, or roughly half the radius. This variance is large enough to create difficulties in obtaining bubble size directly from the traces.

The bubble size distribution function, $B(\zeta)$, discussed by Bankoff and Neal [their Equation (2.2)] is reiterated here:

$$B(\zeta) = \int_0^\zeta b(Z)\,dZ \qquad (4)$$

where $Z = r/R$ and $B(\zeta)$ is the probability that the nondimensionalized radius of a bubble striking the probe is less than ζ. The density function, $b(\zeta)$, is the derivative of $B(\zeta)$ with respect to ζ.

To obtain a simple expression for void fraction in terms of the bubble size distribution, a few assumptions will be made. The assumptions are not crucial to the analysis but illustrate the procedure of obtaining void fraction for a simple case. For an infinite flow field, velocity and size of the bubble are independent of the bubble position relative to the probe. If the bubbles are noninteracting, bubble velocity should be a function of radius only (Figure 2). The average bubble transit time for a bubble of radius r is then

$$\bar{\theta}(r) = \frac{\bar{\delta}(r)}{U(r)} \qquad (5)$$

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glects consideration of the movement of the solid in the bed which is important in the chemical reactions in many cases.

The reader will find the material and presentation interesting and provocative, but the state of the art appears to be more appropriate for journal articles and symposia than for a book.

E. R. Gilliland
Massachusetts Institute of Technology

Process Control, Peter Harriott, McGraw-Hill, New York (1964). 374 pp. $13.50.

This book has arrived on the scene just in time to fill a vital need for the professor of chemical process dynamics and control and for his student. It provides an intermediate level text which combines, in an integrated fashion, both automatic control theory and the dynamic response of chemical plant apparatus and its associated control system.

Previously one could choose only from the elementary texts in the field, such as those of N. H. Ceaglske, G. D. Shilling, or T. J. Williams and V. A. Lauher, or from the quite advanced and specialized texts such as Campbell's *Process Dynamics*. Many thus chose one of the many excellent texts of the mechanical or electrical engineering fields at the sacrifice of applications and examples from the chemical field. Therefore Professor Harriott's text should find a welcome reception at our universities and colleges.

This book further justifies its choice as a textbook by a natural breakdown into three progressively more comprehensive and more difficult areas of discussion; by a wide choice of problems at the end of each chapter; by the use of excellent illustrative examples and figures, and by a quite complete author and subject index and table of nomenclature and symbols.

Chapters 1 through 7 of the book can be considered as a review of the basic concepts of automatic control with attention focused on the mathematics of automatic control and on the use and the dynamic response of typical automatic control equipment. While similar to the treatment given in any good text on automatic control, regardless of the field of engineering involved, this section does correlate the theory quite well to the field of chemical engineering through the use of examples taken from the chemical process area.

A second section comprised of Chapters 8 through 13, less 11, and Chapter 16 presents a comprehensive view of several of the specialized areas of the chemical process control field such as control valves and their use, level control, flow control, pH control, theory and use of complex control schemes such as cascade control and feedforward control, and methods of obtaining optimum controller settings.

The third section, Chapters 11, 14, and 15, gives excellent reviews and discussions of the three major areas of chemical process dynamics and control investigation today—heat exchangers, distillation columns, and chemical reactors.

Despite its overall excellence, the book does have some drawbacks which perhaps should be called to the reader's attention for his evaluation of their importance. Foremost of these concerns the problems following each chapter. Many of them might be difficult for the student at the level of knowledge he will presumably have when he encounters them. Several others call for the use of data from the literature or the reference to other independent textbooks, some of which are relatively old. Second of this reviewer's concerns relates to the author's choice of subject matter. It would be a major aid to the student if the subject of temperature control in general could have been treated to the extent of level control, flow control, etc. This is particularly important since such systems tend to have an entirely different level of time constants, etc. The subject of heat exchangers is well covered but is only a part of the temperature control field. Likewise, the subject of analytical instrumentation application and response, which is becoming so vital to chemical process control, is effectively limited to the discussion of pH control in Chapter 16. Perhaps both of these important subjects will be greatly expanded if and when a second edition is prepared.

The textbook *Process Control* is thus one which is highly recommended for any two-semester senior level or beginning graduate student course in chemical process dynamics and control.

Theodore J. Williams
Monsanto Company

Advances in Heat Transfer—Vol. 1, Edited by Thomas F. Irvine, Jr., and James P. Hartnett, Academic Press, New York (1964). 459 pages. $18.00.

The publishing industry provides a useful service to the scientific community and earns a significant income by marketing collections of review articles which are variously entitled "Progress In . . .," "Annual Reviews of . . .," "Modern Developments In

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$$\alpha = q \int_0^{\zeta_{max}} \{[\bar{\delta}(\zeta)\, b(\zeta)]/U(\zeta)\} d\zeta \quad (11)$$

It should be noted that $b(\zeta)$ is a measurable quantity, but that it represents only the population of bubbles striking the probe. There are more small bubbles existing in the pipe than are indicated by $b(\zeta)$, since the larger bubbles have a better chance of striking the probe. If a distribution function for all bubbles crossing the plane of the probe were designated $H(\zeta)$, then

$$H(\zeta) = \int_0^{\zeta} h(Z)\, dZ \quad (12)$$

where $h(\zeta)$ is the probability that the bubble radius is less than ζ. The quantity $h(\zeta)$ could be determined by photographic studies. When the assumption of uniform distribution of bubbles over pipe area is used, the expression for void fraction is

$$\alpha = Q \int_0^{\zeta_{max}} \{\bar{\delta}(\zeta)\, \zeta^2\, h(\zeta)/U(\zeta)\} d\zeta \quad (13)$$

The relationship between density functions for bubbles passing the plane of the probe is

$$q\, b(\zeta) = Q\, \zeta^2 h(\zeta) \quad (14)$$

The point of the discussion of h is that bubble size distributions from probe contact and from photographs differ by a bubble area weighting factor.

BUBBLE TRANSIT TIMES FROM THE DENSITY FUNCTIONS

The output signal from the probe consists of pulses whose time durations are bubble transit times. If bubble shapes and velocities are known, these transit times may be used to determine the bubble size distribution. Reference *1* presents Equation (3.5) which relates transit time to bubble diameter by

$$D_B = C_1\, \theta_B\, U_B \quad (15)$$

The constant C_1 depends on bubble size and probe distance from the pipe wall. If the probe-to-wall distance is less than the bubble radius, the average chord pierced by the probe is shorter than the length defined in Equation (3), causing C_1 to be greater than for smaller bubbles. For spherical bubbles not influenced by the pipe wall, C_1 becomes 3/2. The following discussion will consider only the case of C_1 not influenced by the pipe wall.

The simplest case is that of spherical bubbles possessing the same radius and velocity. The time-duration distribution, $P(\theta)$, is given by

$$P(\theta) = \int_{\tau=0}^{\theta} p(\tau)\, d\tau \quad (16)$$

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. . .," "Advances In . . .," etc. It is the expressed intent of the authors of this latest addition to the "Advances In . . .," to bridge the gap between the regularly scheduled journals and the university-level textbooks and enable a nonspecialist reader to make engineering use of highly condensed journal articles.

The primary function of the editors is to prevail upon authors of competence to undertake the effort to produce the review and deliver it by a deadline. Absence of further editorial action as indicated by differences in style, nomenclature, and literature citations is generally the rule and is also true of this work.

In their primary responsibility the editors have chosen well in selecting topics and authors but show a heavy bias toward academic contributors. Authors from Russia and Italy give the book an international flavor, and the bibliographies provide a lead into the continental literature for those who tend to consider only English language publications.

The six contributions are summarized briefly below.

"The Interaction of Thermal Radiation with Conduction and Convection Heat Transfer," by R. D. Cess, is an exposition of the effects of the interactions rather than a comprehensive treatment of the entire problem. By the use of simple models, estimates of the magnitudes of effects are illustrated. The error of assuming superposition for grey bodies is emphasized. Only literature of the United States is cited and comparison made to only one experiment.

"Application of Integral Methods to Transient Nonlinear Heat Transfer," by Theodore R. Goodman, is a *tour de force* in approximate methods of solving partial differential equations. The emphasis is on applied mathematics and various approximations are compared by numerical examples. The techniques described are equally applicable to problems other than heat transfer, and this review is highly recommended to the mathematically inclined.

"Heat and Mass Transfer in Capillary-Porous Bodies," by A. V. Luikov, is probably the weakest contribution in the volume. The English is awkward, and the inclusion of detailed experimental description and raw tabulated data detracts from the review nature of the article. Inclusion of theoretical information readily available in reference *19* is superfluous, and neglect of important work in western literature is inexcusable. The editors appear briefly in a footnote on page 137, and this reviewer wished their hand had been heavier and the article more representative of the well-deserved reputation of Professor Luikov.

"Boiling," by George Leppert and C. C. Pitts, could probably be expanded into a book. It represents the continuing work of Professor Leppert since his own early involvement in the Atomic Energy Commission's water heat transfer program and is a welcome updating of J. W. Westwater's classic review. The whole gamut of surface phenomena, bubble dynamics, stability of interfaces, and effect of gravity is covered. Many excellent photographs are used, and extensive reference is made to report literature. Because report literature is important, it is difficult for someone just entering such a field to have access to the source of the reports. This makes their abstraction and correct citation more urgent.

"The Influence of Electric and Magnetic Fields on Heat Transfer to Electrically Conducting Fluids," by Mary E. Romig, is a sleeper. The author will probably become better known for this outstanding review of a new and rapidly expanding area. This scholarly study cuts across the boundaries of hypersonic flow as well as natural and forced convection and includes a concise summary of the principles of MHD. Recent publications in the area of this topic makes one wish the cutoff date in the bibliography had not been early 1962 but early 1963, since the book was published in 1964. Inclusion of the effect of strong electric fields on nonconducting liquids would also have been desirable.

"Fluid Mechanics and Heat Transfer of Two-Phase Annular-Dispersed Flow," by Mario Silvestri, is the longest contribution (92 pages) and the only one to add a supplementary list of references. The text is divided almost equally between heat transfer and fluid mechanics. Professor Silvestri liberally illustrates his work with experimental details and results from his own laboratory. All units used in formulas or illustrations are metric regardless of the origin of the work, although British units are often quoted in parallel. The literature survey is diverse and covers European, Russian, and English langauge publications and reports. The only significant flaw in this review is the lack of care shown in the spelling of names and proper citation of literature. This lack of care is illustrated by the double inclusion of the paper of Owens on page 445.

The carelessness in spelling and transliteration of Russian names is also evident in the rather complete author index where duplicate listings of au-

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thors occur because of misspellings or incorrect initials. In spite of these annoying details, the volume sets a high standard in freedom from serious errors. Because the contributions are from such dissimilar specializations, the book can be recommended for purchase only for persons of very broad interests. For the library of a university or research organization with heat transfer interests, it is a must.

David Miller
Argonne National Laboratory

ERRATUM

Figures three and five of the article, "Resistance to Mass Transfer Inside Droplets" by A. H. P. Skelland and R. M. Wellek, which appeared on page 491 of the July, 1964, issue of the *A.I.Ch.E. Journal,* should be interchanged.

The figure captioned Figure 5 corresponds to the Kronig and Brink model, and the figure captioned Figure 3 relates to Equation (9).