One type of response would be that there is no problem and that all is well. Others, however, would probably recommend a massive reorganization of chemical engineering education . . .

matics, and the computer, to a new approach that not only recognizes and maintains those gains but also clearly links them to engineering practice.

How do we do this? We do it by changing the style and philosophy of teaching our undergraduate courses. At the risk of oversimplification, the following points should be considered:

- **Continue to teach fundamentals, but emphasize the first principles even more strongly.**
- **Make the greatest possible use of phenomenological approaches.**
- **Clearly delineate the progression, use, and relationships between theoretical, semi-empirical, and empirical approaches.**
- **Emphasize practice by continually interlinking theory to actual or real situations. Do this quantitatively; if unable to do so, use qualitative and/or anectodal examples.**
- **Build on first principles by using homework or examination problems that emphasize applications in different, new, or novel areas or applications (*i.e.*, enable the graduate to move into new areas of technology).**
- **Put mathematics into its proper perspective (*i.e.*, useful and important, but not the be-all or end-all).**
- **Use the computer, but emphasize that it is a means, not an end, and that garbage in gives garbage out.**
- **Work into each course the concepts of process and equipment.**
- **Emphasize innovation, creativity, and ingenuity, remembering that an engineer is a "person who carries through an enterprise by skillful or artful contrivance."**

A response to the preceding might be that we already do these things in academia, so why bother? It should be evident that even if we are doing them, as academics we are falling short and must therefore emphasize them even more strongly.

Another comment might be that these are admittably worthwhile objectives, but how can they be implemented? A possible scheme for implementation in chemical engineering departments would be to:

- **Commit to a teaching philosophy that emphasizes the preceding points as well as others that accomplish the same goals.**
- **Take advantage of the valuable resource of faculty with industrial experience to track the undergraduate core courses so that theory and practice can be effectively interlinked.**
- **Utilize, as well, those faculty members who specialize in experimental research so that the aspects of equipment and processes can be emphasized.**
- **Develop good rapport with industry so that examples, guest lecturers, *etc.*, can be used to enrich core courses.**
- **Build on science and mathematics, but clearly emphasize the fact that engineering is different.**
- **Evaluate all of the preceding by contacts and discussions with recent graduates and more mature practicing engineers.**
- **Keep the undergraduate curriculum dynamic, recognizing that static situations produce deterioration.**

Hopefully, this paper will stimulate discussion and more detailed consideration of undergraduate education in chemical engineering. This in itself would be a rewarding and beneficial exercise. ❐

ChE ***book review***

VISCOUS FLOWS: THE PRACTICAL USE OF THEORY

by Stuart Churchill
Butterworths, 80 Montvale Avenue , Stoneham, MA 02180; $52.95, 602 pages (1988)

Reviewed by
Stanley Middleman
University of California, San Diego
La Jolla, CA 92093-0310

Professor Churchill has produced a textbook aimed at the student with prior background in fluid dynamics, although he states that it has been used with "surprising success" as a first course for undergraduates when the material is presented at a slower pace and with some deletion of detail. My own impression is that this book could indeed be used in a junior-level fluids course, but that its success would depend to a great degree on the skill of the teacher in choosing the topics to be included, and in supplementing the material of the text with ample classroom discussion so as to provide a broader context in which fluid dynamics is seen as an essential element of chemical process engineering. In the hands of a teacher whose main focus would be on the derivation of solutions to various fluid dynamics problems, the use of this text would be less successful in providing

Continued on page 111.

REVIEW: Viscous Flows

Continued from page 97

an appropriate background in fluid dynamics. Since there are those among us who do bring this focus into our undergraduate classes, some thought must be given to the selection of this book for a first undergraduate course.

Professor Churchill has laid out the book in a logical and attractive manner. It begins with several chapters on one-dimensional laminar flows. These flow fields are physically appealing and mathematically tractable for the undergraduate, and they provide a foundation for some of the later material. As is the case with most fluids texts, the flows illustrated are almost entirely newtonian (though there is a short chapter on non-newtonian flow through channels) and flows in which surface tension plays a dominant role are barely mentioned. This is a choice an author must make in order to keep the size of the text manageable, and it is a defensible choice. Extensive referencing makes it possible for the introduction of additional material by the teacher or by the self-motivated independent student.

Following this introductory material there is a presentation of the Navier-Stokes equations and a discussion of the special cases of creeping flow and inviscid flow. Several subsequent chapters treat boundary layer flows in great detail, with special attention given to a comparison of experimental results with the mathematical models for these flows. Similarly, flows over solid cylinders and spheres are discussed with extensive comparison of theory to observations on the structure of the flow (wakes, eddies, *etc.*) and on drag coefficients for these bodies. A long chapter on bubbles and drops, illustrating the role of the deformable interface (here, of course, surface tension enters) is presented. There is almost too much material here—I found myself bogged down in the seeming repetitive presentations of data on terminal velocity of rising bubbles.

On the whole, I think this text is a viable option for introduction into the undergraduate curriculum, with the reservations regarding the importance of the instructor that I have indicated above. It would be an excellent choice as the basis for a second course in fluid dynamics.

One criticism of this textbook arises first upon reading Chapter 10, which presents a long (seventy pages) description of various flow fields that are exact solutions of the Navier-Stokes equations. Here the author has an opportunity to introduce a number of practical applications of theory (note the subtitle of the book) but this is not done either through worked examples within the chapter or through the introduction of problems at the end of the chapter. Of the 105 problems that follow Chapter 10, most are of the form of "reduce the equations," and "derive an expression." Only four of the problems are stated in a form that implies a clear practical use of the theory presented in the chapter. I am disappointed that in a text with this prominent sub-title there is so little illustration of the practical use of theory.

If the feature of the text which I have just critized were only a matter of author's choice and style, one could accept the text as it stands since there is so much of it to applaud. Unfortunately, the failure to give more attention to practical applications, in favor of derivations of solutions, leads on occasion to comments that are at least confusing and which are potentially misleading.

For example, a derivation is presented on pages 182 and 183 for the radially outward flow field generated by pressure within a porous cylindrical reservoir of fluid. This is an *extensional* flow field, and extensional flows are important and are often neglected in typical fluid dynamics texts. The solution for the radial distribution of pressure is derived and the statement is made that the pressure is independent of viscosity because there are no shear stresses. To most students this would imply that extensional flows do not exhibit viscous effects, which is clearly at odds with experience and intuition. The introduction of an example at this point, showing how to calculate the pressure required to drive this flow at a specified volumetric flowrate, would serve to clarify this point, with the bonus that the student would be introduced to the concept of balancing the *total* radial stress (which includes the radial *viscous* normal stress) at the boundary of the flow. This would permit the student to learn and appreciate the distinction between shear stresses and normal stresses.

Practical applications of the theories presented, as well as of the empirical correlations of data described so extensively in many chapters, do appear in several chapters more than in others. For example, in Chapters 19 and 20 the topics of flow through porous media and sedimentation and fluidization are covered in considerable detail, and a number of problems at the end of each chapter provide an opportunity for the reader to explore the use of the material in several practical contexts. Thus, this text is not devoid of practical applications. I just would have hoped for more of them in view of the implication of the subtitle of the text. ❐