further by treating Michaelis-Mention (or Langmuir-Hinshelwood-Hougen-Watson, not to mention Briggs and Haldane) kinetics in detail. Finally the phase plane, multiple scale expansions and linearization are introduced in connection with the simple pendulum.

After the virtuosity of this second movement, the third movement (just to mix my metaphors absolutely and uniformly) is relatively traditional. It provides an introduction to the theory of continuous fields and their associated partial differential equations, considering first the elastic vibrations of a bar, then continuum mechanics and inviscid flow and, finally, potential theory with an acoustical example. In a second volume we are promised more continuum mechanics, with Cartesian tensors viscous flow and elasticity, dispersive wave theory and variational methods.

In short it is a book that can be recommended without reservation both for its style and content. It can be recommended for chemical engineering courses; for the chemical engineering student—the least parochial of the engineering family—will welcome the catholicity of example which the chemical engineering teacher will find much instruction in working up further examples of his own.

An Introduction to Nonlinear Continuum Thermodynamics

by Gianni Astarita
Societa Editrice di Chimica, 133 pp.

Reviewed by Martin Feinberg,
University of Rochester

Since the turn of the century anyone who has set pen to paper in an attempt to advance thermodynamics has come under attack from one quarter or another, and the only thing upon which we all agree is that Gibbs was a very smart fellow. So, not knowing what to make of the battles raging around us, we opt for neutrality: we confine our teaching to the substance and style of 19th century thermodynamics. Although this course of action has served us reasonably well and, incidently, lends the subject an undeniable charm, at some point we must ask if such a state of affairs is to prevail forever.

It might be argued that, before we commit our classrooms to anything new, we ought to sit back and wait until the relative merits of various 20th century theories are settled by experiment. Well, I don't think things work that way for a subject as broad in scope as thermodynamics. What happens, I suppose, is that a theory is offered by Professors A,B, and C, is learned and found compelling by Professors X,Y, and Z, who in turn teach the theory to students, write textbooks, try their best to make converts of colleagues, and so on. If the theory has appeal and/or the political climate of the day is favorable, it penetrates into and diffuses through the mainstream of scientific thinking and ultimately flourishes if, in a sense difficult to make precise, that theory is "successful" in applications.

In 1963 Bernard Coleman and Walter Noll published a paper[1] which articulated a simple, yet powerful, line of thermodynamic reasoning based upon the Clausius-Duhem inequality and, by way of example, demonstrated how that line renders results for familiar classes of materials—e.g., linearly viscous fluids which are Fourier heat conductors. In 1964 Coleman published a remarkable paper[2] in which he used the methods proposed a year earlier to deduce results for materials with fading memory (e.g. polymer solutions and melts). Since then the theory has been explored and used extensively by others (notably Gurtin) in an explosion of papers generally endowed with high technical excellence. One can never be certain of these things, but I believe the body of theory precipitated by the Coleman-Noll paper of 1963 will, in fact, be "successful" and will come to play a permanent role in the way chemical engineers think about thermodynamics.

If this is so, then Professor Astarita's monograph must certainly be regarded as an important step in the coming assimilation process. Although it is not the first volume which describes modern methods based upon the Clausius-Duhem inequality, it is, I believe, the first written by a chemical engineer with other chemical engineers predominantly in mind. As such, the book is likely to be a critical, if not decisive, factor in the manner with which our colleagues and students respond to the theory, at least in the immediate future.

Before I discuss the monograph in detail, let me state my own biases plainly. I admire the work Astarita admires, probably for the same reasons. Plausible premises are stated clearly at the outset (to be accepted or rejected as one sees fit) and conclusions are drawn from these using standards of logic, rigor, and linguistic precision normally insisted upon in all other areas of science we deem

Continued on page 133.

This is of course a great deal to claim for one short course, and one may well ask whether simply going through the calculations together with their instructor constituted a significant learning experience for the students. My own impression is that we were able to keep together as a group, and that student comprehension was good—surprisingly good. The students themselves, when surveyed several weeks after the course was over and the final grades were in, indicated that they had understood most of what we covered (see survey results below). On the basis of the written final reports they prepared presenting their results, and our close contact in class, I feel their evaluation is substantially correct.

I think the experiment was very encouraging, and that the idea of offering freshmen a course in chemical plant design well merits consideration. □

REFERENCES

1. Youngquist, G. R., *Chemical Engineering Education*, Winter 1975.
2. Peters, M. S. and Timmerhaus, K. D., *Plant Design and Economics for Chemical Engineers*, McGraw-Hill, 1968.

BOOK REVIEW: Astarita

Continued from page 125.

"mathematical." Moreover, originators of the theory offer no promises of insight into structure and evolution of living things, of the stability of societies, or of anything else so grand. Indeed, their interest in the past few years has been focused not upon thrusts toward trendy applications, but rather upon critical and scholarly reexamination of existing theory.

I appreciate all of this, and that is why I was predisposed toward Astarita's viewpoint before the book was sent for review. It is also for this reason that, upon reading the book, I probably reacted more sharply to shortcomings than would someone less interested in its success. Before I describe the book and point out what I think are its blemishes, let me state in unequivocal terms that I think Professor Astarita has made a bold and important contribution to our literature and, considering the brevity of the book, has rendered a surprisingly effective exposition of difficult material. He has served us well.

Chapter 1 is devoted to mathematical preliminaries. Readers who have not been exposed to mathematics required for, say, a graduate course in fluid mechanics are not likely to find this chapter adequate; on the other hand, readers who have had this exposure but little more will find it helpful. Some of the "preliminaries" offered (orthogonal tensors, covariant and contravariant components of vectors and tensors) are never used in the book and might just as well have been omitted.

Chapter 2 is similar to the first chapter of Truesdell's monograph[3] insofar as it tentatively deals with thermodynamics of homogeneous systems, primarily as a vehicle for sketching the Coleman-Noll methods.

In Chapter 3 the familiar field equations for balance of mass, momentum, and energy are discussed, the local form of the Clausius-Duhem inequality is placed alongside these as a thermodynamic postulate, and the stage is set for demonstration of how that inequality serves to place restrictions upon constitutive equations.

In Chapter 4, application of the theory is demonstrated through successive consideration of ideal fluids, viscous fluids, and elastic solids—all regarded as heat conductors.

Chapters 5 and 6 are devoted to Coleman's study of implications the Clausius-Duhem inequality has for materials with fading memory. The development is closer in technical detail to Day's exposition[4] of the same subject then it is to Coleman's 1964 paper.

In discussing what I regard to be the book's weaknesses I should point out that these are more tactical than they are technical. It is important to make a distinction between, on one hand, the *methods* introduced by Coleman and Noll in 1963 and, on the other hand, Coleman's application in 1964 of those methods to materials with fading memory. The first should, I think, be given clear priority in an introductory work; fortunately, the methods are brilliant in their simplicity and can be taught clearly without much need for advanced mathematics. The second is likely to interest a more limited audience and requires such delicate functional analysis that any brief treatment intended for chemical engineers must, of necessity, be more suggestive

Continued on page 151.

file of reaction engineering problems. This file, which has been organized and maintained by manual methods with no great effort, has been found to be very useful in an educational environment. It should be obvious, moreover, that these same methods should be amenable to other instructional areas of chemical engineering. Thus, one should be easily able to construct similar files, if one is interested, for such areas as thermodynamics, unit operations and process control, to name a few. □

REFERENCES

1. Abramson, H. I., *Chem. Engrg. Progress, 60*, No. 8, 88 (1964).
2. Cushing, R., *Chem. Engrg.*, 73, Jan. 7, 1963.
3. Holm, B. E., *Chem. Engrg. Progress, 57*, No. 6, 73 (1961).
4. Morse, R. and Wall, E., *Petroleum Refiner*, 263, May, 1961.

BOOK REVIEW: Astarita

Continued from page 133.

than precise. Professor Astarita attempts to explain the *methods* in a setting which anticipates the heavy technical needs of the final chapters on fading memory, a strategy which I think taints his exposition of fundamentals with a vagueness impossible to avoid in such an ambitious undertaking.

For example, I believe Chapter 4 is seriously flawed by its opening section which, in anticipation of Chapter 5, deals with differentiability of functionals with respect to present values of temperature. This discussion is too vague to be of much use, plays no real role in the balance of the chapter, and is likely to detract from the effectiveness of the pedagogically critical sections immediately following. I wish Professor Astarita had chosen to divorce his exposition of methodology from his skillful, but necessarily sketchy, description of Coleman's work on fading memory.

I wish also that literature citations had been heavier so that readers could more readily make contact with the original literature—indeed, the crucial Coleman-Noll paper of 1963 is not cited at all.

Despite these remarks, let me state once again that the book is an important one for academic chemical engineers and might substantially influence the way we think about thermodynamics. It deserves reading, as do the source papers and the monographs by Truesdell and Day. Professor Astarita has reached beyond our own literature and brought to it something of value.

REFERENCES

1. Coleman, B. D. and Walter Noll, The thermodynamics of elastic materials with heat conduction and viscosity, Archive for Rational Mechanics and Analysis, *13*, 167-178 (1963).
2. Coleman, Bernard D., Thermodynamics of materials with memory, Archive for Rational Mechanics and Analysis, *17*, 1-46, (1964).
3. Truesdell, Clifford, *Rational Thermodynamics*, McGraw-Hill, New York, 1969.
4. Day, William Alan, *The Thermodynamics of Simple Materials with Fading Memory*, Springer-Verlag, New York, 1972.

WARD: Process Model-Building

Continued from page 139.

ACKNOWELDGMENT

Financial assistance from Combustion Engineering helped make these projects more effective than they might otherwise have been.

REFERENCES

1. Shukis, S. P., and Green, R. C., "Reduce Costs With Scale Models," *Chem. Eng., 64*, 6, 235, (1957).
2. Myers, L. A., "How duPont Saves Money With Models," *Petroleum Refiner, 38*, 7, 121, (1959).
3. Hammar, W., and Duncan, L. Jr., "Union Carbide Builds Scale Models First," *Petro/Chem. Eng., 37*, 11, 56, (1965).
4. Klima, B. B., and Youngblood, E. L., "Inexpensive Plant Models Easily Made," *Chem. Eng., 6*, 4, 128, (1969).
5. Miller, R. E., "Scale Modeling of Large and Small Plant Projects," *Chem. Eng., 78*, 27, 69, (1971).
6. Babcock, J. A., "How To Get The Most Out of Engineering Models," *Chem. Eng., 80*, 4, 112, (1973).
7. Rosenthal, H., and Matuny, M. J., "AIDS - Piping Isometrics By Computer," *Heat Engineering, 45*, 8, 113, (1972).
8. Michel, A. E., "Use of Models in Design and Construction," *Chem. Eng. Prog.*, 54, 3, 86, (1958).
9. Seidel, J. J., "Scale Models Help Plan Equipment Replacement," *Chem. Eng., 64*, 11, 286, (1957).
10. Keishaw, H., and Hollowell, A. F., "Models: A New Maintenance Tool," *Petroleum Refiner*, 37, 1, 132, (1958).
11. Love, F. S., "Troubleshooting Distillation Problems," *Chem. Eng. Prog.*, 71, 6, 61, (1975).
12. Hooper, W. B., "Predicting Flow Patterns in Plant Equipment," *Chem. Eng., 82*, 16, 103, (1975).
13. *Chem. Eng., 75*, 4, 70, (1968), *81*, 27, cover, (1974), *82*, 13, 108, (1975); *Heat Eng., 46*, 1, 4, (1973), *46*, 1, 4, (1973), *46*, 1, 16, (1973).
14. *Nuclear News, 13*, 9, 80, (1970), *14*, 14, 36, (1971), *15*, 4, 71, (1971), *15*, 7, 60, (1972), *15*, 8, 1, (1972), *18*, 4, 19, (1975), *18*, 11, 57, (1975).