into eight sections where the state of affairs in various technical areas is discussed in more detail. The last section contains a single, thought-provoking chapter by Morton Denn on the "Identity of our Profession," in which he argues that the profession has been undergoing evolutionary, rather than revolutionary, change in recent years. Denn points out that chemical engineering has traditionally been viewed as the engineering profession that deals with applications in which physical and chemical rate processes are limiting, and argues that this is the unchanging paradigm to this day. Much of the material in the eight technical sections of the book are certainly consistent with this view. It is amusing, however, to see that the same cast of characters that gave birth to the Amundson Report, *Frontiers in Chemical Engineering* (published in 1988!), which argues that our profession is going through revolutionary changes and is in need of a new paradigm, are here on record (pp. 573-586, and elsewhere) as stating the opposite.

In between the big issues discussed at the beginning and end of the book, there are sections on: Fluid Mechanics and Transport; Thermodynamics; Kinetics, Catalysis, and Reactor Engineering; Environmental Protection and Energy; Polymers; Microelectronic and Optical Materials; Bioengineering; and last but not least Process Engineering. Each section contains two or three expository chapters that make accessible and enjoyable reading. In general, the authors have put their subject matter in both an historical and broad scientific context that is absent from most technical papers and textbooks. This provides a framework for viewing the current state of the art as well as future needs and opportunities.

It is unfair to cite only a few authors since so many are deserving of mention. Nevertheless, I cannot resist mentioning a few personal favorites. I found the three papers on fluid mechanics and transport phenomena very interesting not only for their technical content but also for raising the issue of teaching nonlinear dynamics and analysis to chemical engineers. This was picked up as an item for discussion on pp. 109-122. Large chunks of modern chemical engineering revolve around nonlinear models, which should obviously be treated in a proper context in order to extract the maximum information from them. Even thermodynamics and distillation can be put in this setting to good effect. Few chemical engineering departments, however, teach a course on this subject. It would be nice to think that this book can be used to justify the wider teaching of nonlinear analysis to chemical engineers.

I also found the three chapters on thermodynamics most enjoyable. In recent years there have been impressive strides made in the area of statistical mechanics and there is a general consensus that the future looks bright for molecular theory and simulation. It is also not hard to imagine quantum mechanics finding its way into the chemical engineer's toolchest over the next 10-20 years just as statistical mechanics has in recent decades.

Alex Bell's paper on reaction engineering ( as well as the other chapters in that section) prove that the subject is not dead, in spite of its obituaries in other parts of the literature. John Seinfeld writes informatively about environmental issues and identifies many interesting opportunities for research. Matt Tirrell does likewise for polymers. The chapters in Sections VII and VIII on Microelectronic and Optical Materials, and Bioengineering, respectively, are quite accessible to the nonexpert and provided this one with a good perspective of those fields. The final technical section on Process Engineering is closer to home for me and provides an accurate picture of where things currently stand. Art Westerberg's article, in particular, explains how fast computers and new algorithms have revolutionized the field in the last 10-15 years. Jim Douglas touches on an important point that needs raising, namely, once the profession has shifted completely to the microscopic viewpoint we will have to re-invent process engineering in order to develop and build the new processes. Reuel Shinnar also has valuable things to say about this in the discussion on pp. 114, 256 and 577. The question is, who is going to teach engineering to the next generation of chemical engineers?

The only criticism I have of the book is the amazing omission of a section on separations, which are not mentioned anywhere except in passing. Separations have always been, and will continue to be, of such importance to the chemical engineering profession that it is quite incredible to find practically no mention of them, particularly in view of MIT's great contributions to the subject.

A different reviewer would have cited a different collection of chapters for special mention, but I think the overall impression would be the same. The editor and authors have put a tremendous amount of work into this book. They have created something unique which will be of enduring value. My own thinking about the profession has been influenced greatly by reading *Perspectives in Chemical Engineering Research and Education*, and it is hard to imagine anyone not finding many interesting facts and views between its covers. The book admirably achieves its goal of setting the field in *perspective*, and to borrow a phrase from the late P. V. Danckwerts, the book is a lot less boring than its title suggests.

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**Envisioning Information**

*By Edward R. Tufte, Graphics Press, Cheshire, CT, 1990, 126 pp., $48 postpaid*

For the second time in a decade, an unusual book, written and published in an unusual manner, offers expert guidance in the ways of *cognitive art*—the schemes by which we represent factual information visually. Edward R. Tufte, Professor of Political Science and Statistics and a Lecturer in Law at Yale University, has produced a sequel to his landmark 1983 creation, *The Visual Display of Quantitative Information*. Praised by nearly everyone who reads it, the earlier book presented both a history of data graphics (with many illustrations of the best and worst examples on record) and Tufte's unique guidelines for "doing it right." Called a "tour de force" by Princeton's John Tukey, *The Visual Display of Quantitative Information* remained the subject of scholarly reviews seven years after its publication and has sold nearly 140,000 copies.

*Envisioning Information* is a colorful descendant of *The Visual Display. . .* It deals with the best (and worst) ways to represent "the rich visual world of experience and measurement" on a flat page ("Escaping Flatland" in Tufte's words). It extends the domain of the earlier book to the worlds of color and computer graphics and warns of the dangers that go along with too much of either.

Following the style of its predecessor, it teaches by example—and what a set of examples it has! From Galileo's recorded observations nearly 400 years ago of sunspots and the moons of Jupiter to the gripping reality of the Vietnam Memorial, Tufte shows how multidimensional data may be compacted into cogent, printable graphics. He calls his best illustrations "treasures" (and labels his worst "ducks" and "junk"). He values complexity in a graph and argues his point of view by offering fine sketches of 18th-century Paris and of modern midtown Manhattan, various treatments of train schedules, an exploded parts diagram, and the ominous, day-by-day narrative of a dying woman's stay in intensive care. "To clarify, add detail" is the message.

At a time when the computer is making publishers out of nonpublishers, Tufte pleads for restraint, especially in the use of color. He makes his point by showing examples of superbly colored graphics—mountain and ocean maps, a nature scene, postage stamps, even a color-enhanced proof of the Pythagorean Theorem. And then, for contrast he also shows some disasters. There is a white-bordered United States map that virtually glows with what Tufte quotes Josef Albers as calling "$1+1=3$ effects." He shows a cluttered computer screen and labels it a "grim parody of a video game." And there is a particularly offensive "thigh-graph" that substitutes sex appeal for content.

*Envisioning Information* practices its message, and it does so in ways that are both unique and charming. Tufte's books are themselves works of art, with large, wide-margined pages, a rich binding, and an elegant typeface. To lavish such care, the author founded his own publishing house, Graphics Press, and (at high interest rates) even mortgaged his home to do so.

Still more of a departure is Tufte's insistence on maintaining the unity of text and graphics—his illustrations have no captions! Details of its 200-odd figures are woven into the text so that one simply "arrives" at a particular graphic rather than having to "see Figure 10." In exchanges with an earlier reviewer (about both books), Tufte admitted that his noncaptioning scheme might not work for everyone, but that for him it was the better way.

Yet the charm of the book is more than just visual. Edward Tufte's writing style is full of interesting verbal diversions that focus the reader's attention on the goodness (or badness) of his illustrations. He has a rich store of "Tufte-esque" expressions to capture the interest of even the most casual reader. He speaks of "miraculous contraptionary display, dreaded posterization, ratchet effects, obstreperous. . .data, an exhibit chockablock with cliché, and exuberantly bad examples." He actually has a single sentence with 59 verbs! And in what may be his most exotic use of modifiers, he describes rivers that are stretched out in a display of lengths as meandering "boustrophedonically" around a measurement frame (which stretched this reviewer out to the nearest unabridged dictionary!).

So what does all this have to do with chemical engineering? As I looked back through the last 12 issues of the *Journal*, I found a disturbing sameness in the illustrations that we produce. With just a few exceptions there were the standard engineering graphs, equipment drawings, flowcharts, and tabulations that one might have seen 30 years ago. Of course, now there are also electron micrographs and a sizable number of generic displays generated by computer software (that sometimes show more about the software than about the data).

While I grant that a concentration-time curve doesn't offer much latitude for art work, Edward Tufte's books challenge us to look for those situations that do. Many areas of chemical engineering have aspects that are strikingly visual, and some among us have used those situations to advantage: Scriven and Davis at Minnesota simulating liquid-liquid interfaces, Gubbins at Cornell modeling binary phase diagrams, Hill at Iowa State simulating turbulent, reacting flows, and our own work re-creating the Gibbsian thermodynamic models.

I decided to apply Tufte's criteria to the illustrations in the last 12 issues of the *Journal*, and I too came up with extremes. At what I deemed the lower end of the scale I found the computer-generated, 3-D bar graphs by Rodgers and Sparks (October '91, p. 1517) unnecessarily overpowering for the data they represent. At the opposite end was a splendid graphic by Lahey, Acikgöz, and França (July '92, p. 1049) that classifies the domains of three-phase, horizontal flow by means of relative velocities, written annotations, and sketches of visual observations. While these choices reflect my own bias (and say nothing about scientific merit), they show wide differences in what we expect from our figures.

*Envisioning Information* may not be the "Yellow Pages" of chemical engineering, but it tells us a lot about the do's and don'ts of representing data on a page. Edward Tufte has created another "visual Strunk and White" (to mimic a review of the earlier book). As someone who sees visualization as a tool for *doing* science as well as for looking at it, I recommend it highly.

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