3, by expressing it as

$$\frac{Y}{1+Y}=0.1246\frac{X}{1+X}$$

or

$$Y=\frac{0.1246X}{1+(1-0.1246)X}$$

The bottom end of the operating line (X_a,Y_a) is found by converting $x_a = 0.005$ to $X_a = x_a/(1-x_a) = 0.00503$ and $y_a = 0.001$ to $Y_a = 0.00100$. The top end of the line is at $Y_b = y_b/(1-y_b) = 0.0204$. The line through ($X_a$,$Y_a$) that just touches the equilibrium line is then found graphically (see Figure 3). From Figure 3, the operating line which just touches the equilibrium line passes through $X_b \cong 0.18$ which gives $x_b = 0.152$.

The minimum liquid flowrate is now found by an overall material balance.

In = Out

Acetone $$y_bV_b+x_aL_a = y_aV_a+x_bL_b$$

$$0.02(100)+0.005La = 0.001(98.10)+0.152(L_b)$$

$$1.9019 = 0.152L_b-0.005L_a \qquad \text{(B1)}$$

Water $$(1-x_a)L_a = (1-x_b)L_b$$

$$0.995L_a = 0.848L_b \qquad \text{(B2)}$$

Solving the simultaneous Eqs. B1 and B2 gives the minimum liquid flowrate of $L_a = 10.97$ moles per 100 moles feed gas. This compares well with the exact analytical solution of 10.94. It should be pointed out that the traditional solution method takes more time to perform because of the requirement to plot the data. ❒

ChE book review

Engineering Flow and Heat Exchange

Revised Edition
by Octave Levenspiel
Plenum Press, New York and London (1998)

Reviewed by
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This is the first revised edition of this book, first published in 1984. Professor Levenspiel should be commended for producing such an excellent text, written specifically for engineering students. The book is a pleasure to read and offers several amusing problems, all stated in the language of students, with explanations and examples they can easily understand. Very few texts in engineering can make such a claim. I have used this text exclusively since 1992 in my teaching of unit operations to chemical engineering students. The material is broad enough, however, to also be used in mechanical engineering, and perhaps in civil engineering courses as well, to teach flow and heat transfer.

Students (especially undergraduates) tend to sell used textbooks once they finish a subject and pass their final examination. I found, with great pleasure, that *Engineering Flow and Heat Exchange* was not one of those books; seniors use it in their design courses and many graduates keep the book as a reference. This is obviously due to the wealth of information in the book and the ease with which the information can be retrieved and used. Inclusion of compressible and non-Newtonian fluid flow in the fluid-mechanics section and direct-contact heat exchangers in the heat-exchangers section is a substantial achievement and significantly adds to the usefulness of the text.

One example of the book's unique approach to explaining a complex concept through humor and straightforward, easy-to-understand language is illustrated by how Professor Levenspiel explains the concept of equivalent average slurry density in the problem "Counting Canaries Italian Style." The "slurry" consists of canaries flying in the air inside a closed container. Measuring the pressure before and after the canaries are airborne, and using the Bernoulli equation, gives the change in density and therefore the number of "particles" (birds). Ingenious!

As already mentioned, the book is divided into a section on fluid mechanics and a section on heat transfer. The first part includes basic equations for isothermal flowing systems in Chapter 1, and as an example, flow of incompressible Newtonian fluids in pipes and around solid immersed objects in Chapters 2 and 8, respectively. Unlike other similar texts, the theory is kept short and the assumption is that the student has taken a prior course in fluid mechanics. It is assumed, for example, that the student is familiar with the concept of the Fanning friction factor.

Chapters 3 and 4 address compressible flow of gases (through material taken mostly from thermodynamics) and

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reviewers for their excellent comments.

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BOOK REVIEW: *Engineering Flow and Heat Exchange*

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low pressure, "molecular" flows. Here the concept of "molecular slip" is introduced.

Chapter 5 contains, as mentioned above, concepts and problems of non-Newtonian flow explained in a direct and simple-to-understand fashion. The student is reminded that, in general, this complex fluid can be treated as Newtonian with an additional term and all that is required is to find the correction due to the non-Newtonian behavior. Since most fluids in industrial practice are non-Newtonian, the introduction of this material is, I think, crucial. Furthermore, rheometry to measure non-Newtonian behavior is also presented in detail.

The first part of the book, also contains chapters on flow in porous media and in fluidized beds. They are also well written, with many examples and actual industrial applications both solved and presented as homework problems.

The second part of the book, on heat transfer and heat exchanger design, is also enlightening, crisp, and well constructed. Chapters 9, 10, 12, and 13 contain the usual material on different forms of heat transfer, combined heat transfer, and two-fluid heat exchanger design. Here again, it is assumed that the student has taken a previous introductory course in heat transfer since familiarity with, for example, the Nuselt number is required. The material in Chapters 11, 14, and 15 contains unsteady heating and cooling and design of direct-contact exchangers and regenerators—material usually not covered in standard texts. The second part ends (Chapter 16) with a set of recommended problems involving material contained in the book, keeping in mind practical, industrially relevant applications.

There is an extended Appendix with very useful information such as transformation of units, some material properties, dimensionless groups, and values of more important parameters such as heat transfer coefficients in different geometries. The text also comes (available to the instructor) with a set of solutions to the problems in each chapter , with every second problem being solved. The problems in the last chapter (16) all have solutions. The illustrations in the book are inspired and clear, while the nomograms, mostly for heat transfer calculations, are up-to-date and easy to use.

Over all, this is an excellent book, written with the heart. The reader can visibly appreciate this. It should be a permanent fixture on the bookshelf of any engineer who studied or uses fluid flow and heat transfer in his work. ❐