The coefficient β was set to 0.013, to be consistent with the open-loop step tests for the apparatus.[4]

CLOSED-LOOP RESPONSE

A simulation of the closed-loop temperature response to programmed step and ramp trajectories is shown in Figure 1 (the program producing the plot is available from the World Wide Web[6]). The simulated response is very similar to the experimental response shown in Figure 3.6 of Drake.[4] If disturbances had been better modeled as entering the process input, then the alternative IMC-Based PID controllers derived in [5,7] would provide improved performance. A slightly more complex IMC controller would be used [7,9] if zero offset in tracking the ramp had been required.

CONCLUSIONS

The model of a polymer-film-diffusion apparatus was used to teach the design of controllers that can handle discrete process changes. An available MATLAB code[6] demonstrates that two digital IMC-Based PID controllers, implemented in velocity form that switch during transitions between operating regimes, provide high performance for this problem. This paper and the MATLAB program are provided with the hope it will encourage teaching the design of such controllers in undergraduate courses in process control.

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ChE book review

CHEMICAL ENGINEERING THERMODYNAMICS

by Y.V.C. Rao

Sangam Books Limited; 601 pages (1997)

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This beginning intermediate text is a welcome addition to the limited number of texts appropriate to entry-level chemical engineering courses. While the major emphasis of the book is for use in the classroom, employment by more advanced students and practitioners is suggested and is justified by the breadth of material included.

Each chapter of the book begins with a set of learning objectives that is more helpful than the usual one-or-two paragraph introduction informing the reader of a chapter's content. At the end of each chapter, a quantitative summary reviews the material, including the important definitions and equations. A set of review questions (primarily qualitative but sometimes requiring a calculation) and a set of problems pertinent for class use complete each chapter.

The fourteen chapters of the book proceed logically from basic definitions and concepts to more complex topics, but do not become lost in esoteric arguments of little use to undergraduates. Chapters 1 and 2 give the basic definitions of both thermodynamics itself and primary concepts such as systems, processes, properties, energy types, and equilibrium, together with the units used for thermodynamic calculations. Review questions and problems support the text in prompting the student to make sure they understand the material.

Chapter 3, on PvT relations of fluids, discusses real fluids together with ideal gases as a preparation to their use for later application to calculations using the first and second laws. The selection of relations includes the progression of cubic equations from van der Waals to the various modified Redlich-Kwong equations, as well as the virial equation and Pitzer corresponding states. The selection is in line with current industrial use and what I myself would recommend.

The first law treatment is classical, beginning with calculations of various types of processes for ideal and nonideal gases as well as steam. Treatment of control mass and control volume analysis for transient flow processes is much more thorough, but also more understandable than most treatments. Standard thermochemical calculation methods are also included.

The second law treatment in Chapter 5 is again classical, with a good comparison of heat engines and heat pumps and methods for calculation of entropy. Control volume analysis and efficiency calculations are brief, but unusually clear.

In Chapter 6, the mathematical analysis of the state principle, the criteria for equilibrium, the Gibbs-Duhem equation, and the derived energy properties, in my opinion, need not be as difficult as they are presented. This is the only chapter that absolutely needs its summary for understanding and relevance.

Relations among properties and their manipulation by Jacobeans

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ships? Hinder relationships?

- *What is networking (in the human sense) and how can you best accomplish it?*
- *What should you do before, during, and after an interview?*

Note that these questions were designed to test only for increased student awareness of the important skills (which, after all, was the course's main goal) and not for actual mastery of these skills. Furthermore, these questions do not provide a direct correlation to all the course objectives stated earlier. Despite these caveats, an analysis of students' answers (done by an independent, objective assessor[6]) showed that the course was most effective in increasing student awareness of issues related to the interview process, goal setting and prioritization, and effective communication; it was less effective in helping students to identify the skills and qualities that would most help them to be successful in their careers, and in teaching them networking skills; and it was least effective in conveying information regarding time management strategies.

In most cases there is a correlation between a course's effectiveness and students' prior knowledge (as shown in the pre-test). In other words, if students have good prior knowledge about a particular topic (such as time management), then the course was less likely to enhance their knowledge in that area. This finding may be simple common sense, but it highlights the importance of assessing prior knowledge in the planning stage of such a course. Overall, the course did add some value, even though many of the students had at least *some* good prior knowledge on every pre-/post-test question.

SUMMARY

I must admit that I approached the teaching of this course with some trepidation, not knowing how well chemical engineering students would react to a "non-technical" course offered by their home departmant, let alone a course that involved numerous writing assignments. The fear turned out to be unfounded. Students reacted very positively to the discussion of issues that are relevant to their study, their lives, and their careers. They participated actively in class discussion, wrote openly about their aspirations and fears, and were delighted to have the opportunity to place their education in context. I encourage other departments to consider offering such a course to their students. My course syllabus can be found at

http://www.andrew.cmu.edu/course/06-208

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BOOK REVIEW: *Thermodynamics*

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and Bridgman relations are very concisely and logically developed in Chapter 7, together with an excellent discussion of the Clapeyron equation. Chapter 8 uses the derivations of the previous chapter to develop relations for properties of real fluids using each of the PvT relations of Chapter 3 to derive departure functions for both gases and liquids. Graphical and equation representations are given. Property tables and diagrams are briefly discussed.

Chapters 9 through 13 deal with phase equilibria. The first chapter defines and calculates partial molar properties, chemical potentials, and fugacity coefficients, the latter by applying the definition to the various equations of state. Mixing rules and calculations of both thermal and equilibrium properties for real fluid mixtures follow. Chapter 10 discusses stability of equilibrium systems as well as pure fluid phase transitions, vapor pressure, and the phase rule.

Properties of solutions from ideal to very nonideal, simple phase equilibria predictions, and the full Gibbs-Duhem equation and its use, including derivation of excess free energy models for activity coefficient correlation, are given in Chapter 11, together with activity coefficient prediction methods.

Chapter 12 discusses vapor-liquid equilibrium in a methodical and logical way and is a high point of the book. Basic relations used to equate fugacity for both low-pressure and high-pressure systems are detailed with many examples. Tests for VLE thermodynamic consistency are discussed. Qualitative discussions of both vapor-liquid and vapor-liquid-liquid equilibria are discussed and illustrated. A short treatment of dilute solution laws and liquid-vapor-solid solubilities is contained in Chapter 13.

Chemical reaction equilibrium is the subject of Chapter 14, which discusses basic free energy-equilibrium constant reactions, homogeneous gas reactions and the effects of variables, adiabatic reactions, and phase-rule analysis of and calculation of equilibrium for simultaneous equilibrium reactions. A short discussion of simple liquid phase and heterogeneous reactions concludes the chapter. This chapter could be improved by including more material on solid-gas reactions and a discussion of solution of simultaneous reaction equilibria by free-energy minimization.

Appendices include pure component data properties from various sources as well as thermodynamic data for steam and common refrigerants. The pure component data section should be updated to the data now accepted as the most accurate.

In summary, the book is a credit to the author and to his profession. In my opinion, it is definitely competitive with the leading first textbooks in chemical engineering thermodynamics. Faculty, students, and practitioners will all find material of value. The only negative is that the book is softbound and poorly glued; my copy split after very little use. ❒