

ACKNOWLEDGEMENTS

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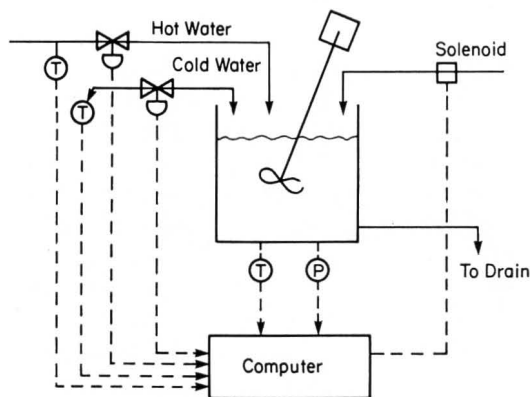


FIGURE 4. Temperature and level control.

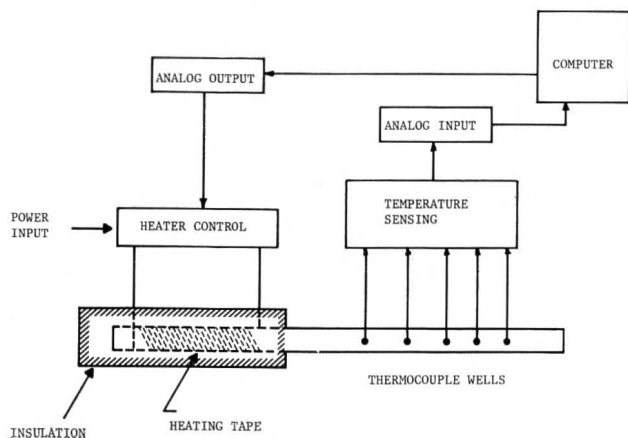


FIGURE 5. Heated bar experiment.

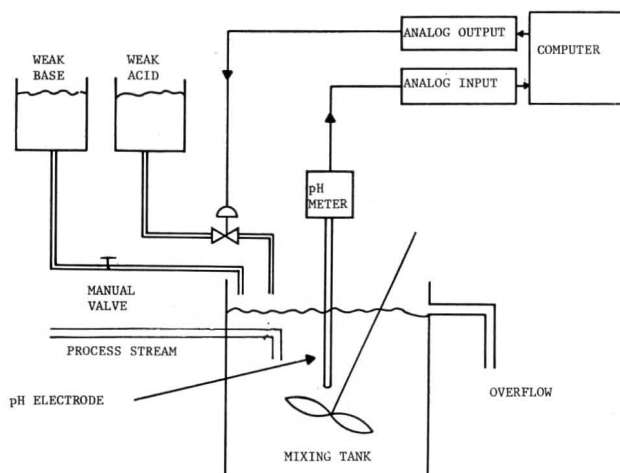


FIGURE 6. pH control experiment.

ing at Washington University for providing financial support for the laboratory through equipment grants. Special thanks to our student, Dale Millard, who worked diligently on the hardware for the experiments and invented the power-controller circuit.

REFERENCES

The following books are used as reference material for the course.

1. *Real Time Computing*, D. A. Mellichamp, Editor, Van Nostrand Reinhold Co., New York (1983).
2. *Computer Process Control*, by P. Deshpande and R. H. Ash, ISA Publications (1981).
3. *Digital Computer Process Control* by C. L. Smith, Intext Publication (1972).
4. *Minicomputers in Industrial Control*, T. J. Harrison, Ed., ISA Publications, Instrument Society of America (1978).
5. *Microcomputers for Measurement and Control*, by D. M. Auslander and P. Sagues, Osborne, McGraw-Hill (1981).
6. *Process Modeling, Simulation and Control for Chemical Engineers* by W. L. Luyben, McGraw-Hill (1973).

ChE book reviews

CHEMICAL AND PROCESS THERMODYNAMICS

by B. G. Kyle

Prentice-Hall, Inc., 1984, xvi + 512 pgs. \$37.95

Reviewed by Truman S. Storvick
University of Missouri-Columbia

It appears that all chemical engineering thermodynamics textbooks are created equal. Each author intends to provide the student with an introduction to the subject and to show how specific applications in process design calculations can only be done by careful applications of the principles of equilibrium thermodynamics. Because this subject is the foundation of all chemical engineering, there have been many books written on the subject.

Professor Kyle has done what all authors have done with this subject the past two decades. He has taken the basic ingredient list assembled by Dodge [1] and by Hougen and Watson [2] and brought it up to date with new experimental data and worked examples. The ordering of the topics is not the same as one finds in the textbooks written by Smith and Van Ness [3] or by Sandler

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graduate literacy and the PhD language requirement. Indeed, I have become so inured to this bias that I was genuinely delighted to receive Professor Siddall's book, "Probabilistic Engineering Design," for review from the editors of this esteemed journal. At long last; somebody cares!

Before editorializing further, let me describe what is in this book and its strong and weak points. Chapters 2-5, in the author's words, "provide a review of the necessary material and background for the text." These 145 pages describe the concepts and theorems of probability, probability distributions, moments of a distribution and generation of probability density functions. The level of scholarship is high, the presentation is excellent and the examples are interesting, current, and pertinent. Although I find myself occasionally disagreeing with Professor Siddall, I admire his courage in telling it like he sees it. For example, only in the Appendix do we find a (brief) discussion of confidence limits for distributions because, the author tells us, engineering intuition is a better basic tool in risk decision making.

The rest of the chapters cover: (6) Probabilistic Analysis (Primarily Monte Carlo and moment relationships); (7) Sequential Events (Markov chains, Monte Carlo, Random Time Functions); (8) Order Statistics and Extreme Values; (9, 11, 12) Reliability and Failure Modes; (10) Design Options (only 14 pages); (13) Optimization (four pages only).

From page 145 on, the treatment and topics become somewhat uneven. Professor Siddall, at times, loses patience with his readers. Advanced Monte Carlo methods are developed in detail; basics are almost ignored. The author assumes that the reader is sufficiently familiar with Lagrangian multipliers and Newton-Raphson techniques that he uses them without explanation (or listing them in the index). Markov chains are accorded one paragraph: we are told that problems that can be solved by Markov methods are better solved by Monte Carlo. One of Professor Siddall's research interests, E. T. Jaynes' maximum entropy principle, is accorded quite a bit of space in this text. Personally, I feel the same way about the maximum entropy principle as the author feels about Markov methods, but why should we agree on everything?

A very nice feature of this book is the copious computer programs which appear throughout. Also, a well documented, 105-page software package for probabilistic design forms one of the Ap-

pendices.

This is an excellent, well-written, interesting book. I enjoyed it, and I am unabashedly pleased to have been cited four times in the Author Index. The crying shame of it all is:

- a) The publisher printed it on cheap paper from typed, hard-to-read copy. The equations occupy too much space, and the price (\$65.00) is outrageous.
- b) Every chemical engineering curriculum should have a required course based on the material in this book: none do. Of course, there is no room for this, and many other things, in our aborted four-year curriculum. If we went to a five- or six-year curriculum there would be; and, if we did this, then maybe the Copley Square Hotel in Boston would not have the Chutzpah to give its head janitor the title of "Engineering Consultant." □

REVIEW: Process Thermodynamics

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[4], for example. Ordering the presentation may be more a matter of style than pedagogical necessity.

The first eight chapters, or about one third of the book, cover the first law, second law, pVT behavior, thermal effects and the calculation of the thermodynamic properties of matter. The classical Carnot engine—Clausius inequality development of the entropy function is used in this treatment. Phase equilibrium and chemical equilibrium each occupy about 100 pages of material. The last 100 pages are given to thermodynamic analysis of processes, physico-mechanical processes and compressible fluid flow. The text is carefully crafted and free of troublesome production errors. There are numerous worked examples and the list of exercises for students seems adequate.

"One may reasonably ask, 'Why another book on thermodynamics; are there not more than enough on this subject now?'" is the opening sentence in the preface to B. E. Dodge's book. Forty years and many textbooks later Professor Kyle has written another traditional chemical engineering thermodynamics textbook. We all agree on the major topics and tradition may have bound us to small variations in development and presentation. If you are using one of the widely adopted textbooks in your course this book could serve you. The best textbook for me and for you is the one our students can read and that matches

our teaching style. Professor Kyle has given us yet another option in that tradition. □

References

1. B. F. Dodge, *Chemical Engineering Thermodynamics*, McGraw-Hill, New York, 1944.
2. Hougen, O. A. and K. M. Watson, *Chemical Process Principles, Parts I and II*, John Wiley, New York, 1947.
3. Smith, J. M. and H. C. Van Ness, *Introduction to chemical Engineering Thermodynamics*, Third Edition McGraw Hill, New York, 1975.
4. S. I. Sandler, *Chemical and Engineering Thermodynamics*, John Wiley, New York, 1977. □

LOST-WORK STATEMENTS

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reversible path that brought the system from State 1 to State 2. But if that path produced useful work, we could have stored it and used it to partly offset the work of restoration; if it produced no useful work, then all of the work of restoration must be supplied externally. Hence the thermodynamic lost work, as apparently first stated by Van Ness [14] is the work to restore the system minus the external work produced.

We can now proceed to complete Table 1, which shows the differences in properties of the two definitions of lost work. The first question is whether they are unambiguously defined for non-isothermal systems. From the definitions in terms of dS_{irr} , it is easy to see that LW_t is unambiguously defined for a non-isothermal system because the system temperature does not appear in its definition (only the infinite surroundings temperature does). The system temperature is implicitly present in the dS_{irr} term, but that is unambiguous. On the other hand, LW_m has a T in its definition in terms of dS_{irr} . If that T is constant, both in space and in time, then the definition is unambiguous. But if it is not, then there is no unambiguous definition of LW_m . For example, we could consider the irreversible flow of heat through a solid conductor from a reservoir at T_h to one at T_c . Here

$$dS_{irr} = dS = dQ \left(\frac{1}{T_c} - \frac{1}{T_h} \right) \quad (14)$$

so

$$dLW_t = T_o dS_{irr} = dQ \left(\frac{T_o}{T_c} - \frac{T_o}{T_h} \right) \quad (15)$$

and

$$dLW_m = T dS_{irr} = dQ \left(\frac{T}{T_c} - \frac{T}{T_h} \right) \quad (16)$$

LW_t is perfectly unambiguous, but LW_m is only defined if we can define a proper value for T . We could set it equal to T_c , in which case LW_m is equal to the work that would have been produced by a Carnot engine withdrawing dQ of heat from the high-temperature reservoir and operating between T_h and T_c . Or we could set it equal to T_h , in which case LW_m would be equal to the amount of work that a Carnot engine would produce by withdrawing $(T_h/T_c)dQ$ of heat from the high-temperature reservoir and rejecting dQ of heat to the low-temperature reservoir. One could persuasively argue for either of these values or perhaps for some intermediate one. The point is that there is no obvious or unambiguous definition of LW_m for this case. Van Wylen and Sliepcevich have tried to deal with this problem. Van Wylen [16] says

In summary, the lost-work concept assumes that there is a reservoir available at the temperature T required for the given situation. The concept of irreversibility assumes heat transfer with the surroundings only at temperature T_o .

Here he is clearly referring only to LW_m and does not mention the existence of the other definition (LW_t). Van Wylen uses another quantity which he calls "irreversibility" which is identical to what we call LW_t .

Sliepcevich [11] says

It is apparent that the evaluation of the terms $\delta(Q_i/T_i)$ and $(\delta l_w/T)$ in Eq. (4-155) [a general entropy balance] will pose certain difficulties either if the temperature of the system is not uniform throughout or if the temperature, even though uniform throughout, changes during the process.

and also

Note that the latter [Eq. 4-193, a steady flow entropy balance using LW_m] cannot be solved explicitly for $(dQ)_i$ or $(dLW)_i$ unless the temperature of the system T is constant and uniform throughout, in which case, $T_i = T = T_i = T_o$. For this very special case, Eq. 4-193 yields....

These three statements must surely have convinced any practitioner that the lost work definition to which they apply, (LW_m), is of very little, if any, practical utility.

The next line on Table 1 asks whether the two values of LW are computable without reference to the surroundings temperature. LW_m obviously is because in its definition, nothing related to T_o appears. One unit of mechanical work converted to internal energy has the same value of LW_m whether it is at the temperature of the sun or that of liquid helium. On the other hand, LW_t cannot be