

behavior due to catalyst deactivation. The current state of art on multiplicity, stability and transient behavior of a fixed bed reactor is also discussed.

After a brief review of imperfect mixing in reactors and age-distribution functions, the analysis and design of the fluidized bed reactor follows. The design principles of such a reactor are discussed in detail within the context of the two-phase theory applied to catalytic reactors. Several reactor models are discussed with emphasis on the assumptions and approximations of each one of them. The analysis of a fluidized bed becomes complete with a discussion of desulfurization with limestone in a fluidized coal combustor.

The trickle bed reactor is investigated next [10]. Emphasis is given to internal and external wetting efficiencies, mass transfer pertinent to trickle flow, and the factors in the design of such a reactor.

An overview of conventional and particularly unconventional optimization concludes this course. Special emphasis is given to globally optimal design [11].

The last stage of this course is a take home final exam. This exam includes a set of data of the methanol synthesis from H_2 and CO (in the presence or absence of CO_2). This is a simple system chemically, the thermodynamic properties of the chemical species are well-known, it has commercial significance, and it is not too simple kinetically. The students have to develop a kinetic model for the synthesis of methanol from that set of rate data; to simulate specified plant-scale catalytic reactors at specified reaction conditions, using their kinetic model; and to summarize their results. They are given the types of reactors, the reaction conditions and most thermodynamic and physical property data. The reactors may be fixed or fluidized beds, one- or two-dimensional, and isothermal or nonisothermal. The purpose of this project is to compare the kinetic models and simulated reactor performance calculations generated by various students working independently from a common data base and set of assumptions. The modeling process itself—by incorporating different interpretations of experimental data into the basic kinetic models—can influence the final reactor design and its ultimate performance dramatically.

Student evaluation of this course has been favorable and their comments indicate that they enjoyed the final project. □

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ChE letters

DEAD STATE NOT A DEAD ISSUE

Dear Sir:

Re: Availability (Exergy) Analysis, and Environmental Reference States (*CEE*, p. 138, Summer 1983)

Nothing pleases an author more than a long and careful review, seasoned with salutary adjectives, of his book [1]. Consequently I am obliged to both the reviewer and the editor for their generosity.

Permit me use of this letter to try to put to rest an issue raised in the review—the proper environmental reference state to be used for availability calculations.

Almost any reference state will do; as long as it can be explicitly defined, is convenient, is used consistently, and is clearly stated to readers and users whenever absolute rather than incremental availability changes are presented.

I have chosen the same reference state used throughout the chemical literature for "Standard Enthalpies of Combustion"—and hence I call the availability values compiled in my book "Standard

Continued on page 197.

concepts and methodologies of a discipline, they are not prepared to imagine how the solution of nonlinear equations (for example) might apply to their discipline. The authors have recognized that interest in computer programming for students of chemical engineering might be enhanced if they could see how the solutions of general classes of problems developed in computer science courses apply to chemical engineering. Their book might be useful for supplementary reading in a course on computer programming, although it is more likely to be useful for independent study by students in their junior and senior years, or perhaps for a short course offered in a chemical engineering department.

The book is at a very elementary level in terms of both computer programming and chemical engineering. The authors discuss briefly each of several general classes of problems and present computer programs (in FORTRAN Extended Version IV) for specific problems in chemical engineering. The first chapter, on the solution of nonlinear equations, for example, includes applications such as solving the virial equation of state, bubble-point and dew-point calculations, and simple flash vaporization. Other chapters deal with simultaneous linear equations, curve fitting, numerical integration and differentiation, linear interpretation, nonlinear simultaneous equations, and plotting. □

LETTER: Dead States

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Chemical Availabilities." This choice of reference state is simple and is compatible with the existing chemical literature, in particular, data on standard free energies of formation. More complex or idiosyncratic reference states defined by European thermodynamicists [2, 3, 5] have been adopted by some U.S. authors [4].

The motivation for these complex reference states appears to be the belief that one needs to and can calculate an absolute or "actual" availability, if the "dead" state of the environment is defined. The "dead" state definition consists of a careful description of the temperature, pressure, and composition of the environment. Once a system's components match this state, the system is "dead" as far as work production is concerned.

The effort to define a "dead" state has yielded a laborious analysis of the average composition of the hydrosphere, atmosphere, and lithosphere to crustal depths [5], and atmospheric "dead" states like that reprinted in the review, wherein the at-

mosphere is at 100% humidity, giving the actual atmosphere a negative availability, in most places for most of the year; and where the reference state for CO₂ requires that tabulated CO₂ free energy must be corrected for the work that may, in theory but not in practice, be obtained by expanding CO₂ from one atmosphere to an assigned atmospheric partial pressure.

There is less utility in computing an "absolute" or "actual" availability, than in computing an absolute energy. The calculation of the former should be done, according to Gibbs, with respect to the "surrounding medium," that is the interacting, local, environment; which is, of course, so dynamic that it is the universal subject of conversation.

Availabilities like energies have relative magnitudes, computed with respect to reference states. A reference state, is a reference state, is a reference state, and *not* a "dead" state. If it is dead now it will quicken as soon as Summer ends ($T_0 = 25^\circ\text{C}$) and the fog lifts ($p_{\text{H}_2\text{O}} = .03 \text{ atm}$).

Sincerely,
Martin V. Sussman
Tufts University

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