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erences at the end of each chapter, particularly of the more recent literature, has been increased. Many new problems have been added and occasionally answers are given. These problems appear to be lengthier and more difficult than those of the first edition but do not require a mathematical facility beyond undergraduate calculus.

The author has retained the clarity of expression characteristic of the previous volume and the typography is excellent throughout. This volume should prove most useful not only to the chemical engineering student but to the practicing engineer desiring to bring himself up-to-date on the state of the art of the several mass-transfer operations.

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Analysis and Simulation of Multiport Systems, Dean Karnopp and Ronald C. Rosenberg, Massachusetts Institute of Technology Press, Cambridge (1968). 221 pages. $10.00.

Dynamic systems have been represented by several methods. The most used method is through differential equations. Other methods that are used are circuit graphs, signal flow diagrams, block diagrams, etc. Each of these have their advantages and disadvantages and are useful for specific types of systems.

The authors introduce a new method, the bond graph, first introduced by Henry M. Paynter in 1961. The authors state that "In order to make the analysis of a large system tractable, the models of the component parts must be rather simple, and it is usually the simpler models within fields of specialization that turn out to be closely analogous to models in other fields. These observations lead one to seek a uniform way to describe dynamic models of physical systems that traditionally fall into specialized categories but do not have a great deal in common". They present the bond graph to accomplish this objective.

To quote again "The mechanism for the convenient and rigorous system of power flow is the bond graph, and the main purpose of this study will be to present rules and methods for working with bond graphs". The concepts and notation are new and therefore the Theory of bond graphs is not as complete as that of more developed theories.

The authors list the goals of bond graph methods, which briefly are:

1. Provide a uniform mechanism for

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Mass transfer driving forces in packed and fluidized beds, Wilkins, George S., and George Thodos, **AIChE Journal, 15,** p. 47 (January, 1969).

Key Words: A. Celite Particles-1, Reactor Bed-1, Actual Driving Force-4, Carrier Gas-5, *n*-Decane-5, Hydrocarbon-6, Bed Height-6, Concentration Gradient-7, Driving Force-8, Packed Bed-9, Fluidized Bed-9, Hydrocarbon Analyzer-10, Steady State-10.

Abstract: The evaporation of *n*-decane into air from the surface of Celite particles has been used for the establishment of mass transfer factors for both packed and fluidized bed systems. For these calculations log-mean partial pressure differences were used. Actual concentration profiles of the transferable component were also experimentally measured by monitoring, at different bed heights, the concentration of *n*-decane vapor present in air used as the carrier gas. This was made possible through the use of an extremely sensitive hydrocarbon analyzer. The resulting profiles were used to obtain by graphical integration the actual driving force prevailing each run. A nearly one-to-one correspondence was found to exist between the actual driving force and the corresponding log-mean value for both packed and fluidized bed runs.

Liquid film flow rates in two-phase flow of steam and water at 1000 lb./sq.in.abs., Singh, Kuldip, W. A. Crago, E. O. Moeck, and C. C. St. Pierre, **AIChE Journal, 15,** p. 51 (January, 1969).

Key Words: A. Two-Phase-8, Annular Flow-8, Porous Sinter-10, Steam-Water-8, Tube-10, Burnout-4, Entrainment-4, Mass Flux-6, Quality-6, Sinter Length-6, Film Flow Rates-7, High Pressure-5, Adiabatic-5.

Abstract: A knowledge of liquid film flow-rates is important for design purposes when accurate predictions are required of the conditions under which dryout heat flux occurs in nuclear reactors and boilers. Liquid film flow-rates were measured for a steam-water mixture in cocurrent, upward annular flow in a tube at a pressure of 1,000 lb./sq.in.abs. Sinters located at the test section exit were used to extract the liquid film after the method of the Harwell group. Sinter lengths of 2, 1, and ½ in. were employed to investigate the effect of length on the extracted liquid flow rates. The test section was a stainless steel pipe I.D. 0.493 in., approximately 200 diam. in length. The total mass flux ranged from 0.2 to 0.7×10^6 lb.m/hr.sq.ft. and the quality varied from 0.3 to 0.92.

The experimental film flow rates were found to increase with decreasing quality. In the range of parameters investigated, the curves of film flow rate at constant quality vs. mass flux showed a maximum at a fixed value of steam velocity. At the same total mass flux and quality the film flow from the ½ in. sinter was lowest suggesting that the crests of high amplitude roll waves overshot the sinter. Film flow-rates were consistently higher than the theoretical predictions using Levy's model. About one-third of the measured flow rates were twice as high as predicted.

Sensitivity of a class of distributed parameter control systems, Sienfeld, John H., **AIChE Journal, 15,** p. 57 (January, 1969).

Key Words: A. Sensitivity-8, Control-8, Distributed Parameter Systems-8, Parameter Variations-8, Algorithm-10, Optimization-9.

Abstract: A sensitivity matrix is defined as a measure of trajectory deviations to small parameter variations of both open and closed-loop controlled nonlinear parabolic and first-order hyperbolic systems. In general the parameters may enter through the system equations or the boundary conditions and may be time or spatially dependent. The introduction of a positive measure of the sensitivity, the norm of the sensitivity matrix, into the performance index is shown to be effective in limiting the trajectory deviations due to the parameter variations. The open and closed loop control of a double pipe heat exchanger is analyzed with the open-loop problem solved by an approximate procedure. The sensitivity reformulation is successful in reducing trajectory sensitivity, however at the cost of decreased overall performance.

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the description of a wide variety of physical systems.

2. Focus on physical systems and power and energy exchanges.

3. A physically based sign convention that is indicated explicitly on the bond graphs.

5. The bond graphs provide a framework for setting up analytical machinery that is physically consistent.

6. Bond graphs provide for ease of simulation either analog or digital.

The book is stated to be a progress report on the theory and application of bond graphs for a study of physical systems. They do not discuss the art of constructing models of physical devices valid for specific cases, however, they do point out the power of bond graphs to produce models based on physical effects.

The reader should be familiar with electrical circuit theory, state space equations, and vector analysis. Examples are in three areas, electrical, mechanical, and hydraulic. The systems used are restricted to those for which a pair of variables exists whose product is a power quantity. This eliminates many systems of interest to chemical engineers, such as heat flow, chemical reactors, steam flow, etc. The book is therefore of limited interest to chemical engineers unless one is willing to develop the theory for the area one is interested in.

Chapter 2 describes the physical systems to be used in the book and defines many of the terms to be used. A port is the point at which there is a power interaction between the component and the environment. Thus, there are 1-port, 2-port, and n-port systems. The bond at a port is associated with a scalor power flow which is a product of two variables. The two variables are called effort and flow for all systems.

Chapter 3 defines a basic set of multiports that are used in the modeling of real systems. The actual component in each case may be electrical, mechanical, or hydraulic. The basic components are 1, 2, 3-port elements. The basic 1-port elements are resistance, capacitance, inertance, effort source, and flow source. The 2-port elements are the transformer and gyrator. Causality (the assignment of input and output quantities) for each of the basic components is discussed.

Chapter 4 develops the methods for finding bond graphs of physical systems by combining the basic components given in Chapter 3.

Chapter 5 develops a systematic procedure for developing the differential equation for the system from the bond graph.

Chapter 6 discusses the relation between bond graphs and block diagrams and signal flow diagrams. The procedure is entirely graphical. Also included is the manipulation of linear 2-port matrices commonly found in some engineering systems.

Chapter 7 discusses the simulation of systems by analog, digital, or hybrid computers. The digital program used is ENPORT developed by A. M. Paynter.

The book is well written. It is difficult to present new concepts in a manner so that readers unfamiliar with the subject will easily comprehend the material. The authors have in most instances been reasonably successful this respect. However, the reviewer had difficulty in some parts of the book. Anyone wanting to use the bond graph method would have to spend some time studying the book. Chemical engineers would have to do considerable research before the method could be successfully applied to chemical engineering systems.

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