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ChE book review

NATURAL GAS ENGINEERING: PRODUCTION AND STORAGE

by Donald L. Katz, Robert L. Lee
McGraw Hill, New York, NY 10020; 760 pages, $54.95 (1989)

Reviewed by
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This book covers most aspects of natural gas engineering. It is a survey suitable for a short course to introduce practicing engineers to the topic. The book is descriptive and as such is much too broad to be used as a textbook. The later half of the book is essentially a monograph recording the senior author's extensive experience in this area. Chapters 1-7 describe the material properties of the system, chapters 8-13 contain the core of the material concerned with the production and storage of natural gas, chapters 14-15 mainly discuss operations, and chapters 16-17 contain miscellaneous topics.

Chapter 1 • *Natural Gas Technology and Earth Sciences.* This chapter is a concise review of natural gas engineering production and underground storage of natural gas. Several subjects are covered, *e.g.,* the branches of petroleum industry, sources of information for natural gas engineering, a brief discussion of geology and earth sciences, and earth temperatures and pressures.

Chapter 2 • *Properties of Rocks.* This chapter contains some descriptions of the properties of rocks or porous media, including a description of how these properties are measured. The discussion is understandable and relatively clear—but very terse.

Chapter 3 • *Thermodynamics: Flow Equation, Fluid Properties, Combustion.* This chapter is basically descriptive. It is terse, explaining how the equations are derived and giving some limited information on how to calculate combustion of natural gas.

Chapter 4 • *Physical Behavior of Natural Gas Systems: Physical and Thermal Properties, Phase Behavior, Analyses.* The initial part of this chapter is a review of pressure, volume, and temperature relationships of pure fluids. The phase rule and the behavior of complex mixtures are briefly discussed.

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later on from first principles. This direction will lead us into what I would call molecular chemical reaction engineering. These and other topics not mentioned here may first be covered (and in some cases are *currently* covered) at the graduate level, but they will filter down to the undergraduate level. This filtering will occur much more rapidly than have analogous topics in the past.

SUMMARY

By arranging the teaching of chemical reaction engineering in a structure analogous to a French menu, we can study a multitude of reaction systems with very little effort. This structure is extremely compatible with a number of user-friendly ordinary differential equation (ODE) solvers. Using ODE solvers such as POLYMATH, the student is able to focus on exploring reaction engineering problems rather than on crunching numbers. Thus, one is able to assign problems that are more open-ended and to give students practice at developing their own creativity. Practicing creativity is extremely important, not only in CRE but also in every course in the curriculum, if our students are to compete in the world arena and succeed in solving the relevant problems that they will be faced with in the future.

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NOMENCLATURE

a catalyst activity
A frequency factor, appropriate units
A_c cross sectional area, m^2
C_i concentration of species i (i = A,B,C,D), mol/dm^3
C_{pi} heat capacity of species i, J/g/K
D_p particle diameter, m
E activation energy, J/mol
F_i entering molar flow rate of species i, mol/s
G superficial gas velocity g/m^2/s
g_c conversion factor
k specific reaction rate (constant), appropriate units
K_e equilibrium constant, appropriate units
L length down the reactor, m
N_i number of moles of species i, mol
P pressure, kPa
r_i rate of formation of species i per unit volume, mol/s/dm^3
r'_i rate of formation of species i per unit mass of catalyst, mol/s/g
t time, s
T temperature, K
U overall heat transfer coefficient, J/dm^3·sK
V volume, dm^3
W catalyst weight, g
X conversion
y pressure drop parameter, (P/P_o)
y_A mole fraction of A

Subscripts

A refers to species A
0 entering or initial condition

Greek

α pressure drop parameter, g^{-1}
β catalyst decay parameter, $s^{-1/2}$
ΔH_R heat of reaction, J/mole A
δ change in the total number of moles per mole of A reacted
ε volume change parameter = $y_{A0}\delta$
ϕ porosity
μ viscosity, cp
ρ density, g/dm^3
ν volumetric flow rate, dm^3/s
❐

REVIEW: Natural Gas Engineering

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There is a discussion of the compressibility of natural gases with an explanation of the various correlations that have been used, including the effects of nitrogen, carbon dioxide, and hydrogen sulfide. There are a few examples that show how to use these particular charts.

Chapter 5 • *Gas Hydrates and Their Prevention.* The formation of hydrates is an important issue associated with the production of natural gas, especially in colder circumstances. The discussion is quite complete.

Chapter 6 • *Applications of Flow Equations: Pressure Drop, Compression, Metering.* The material in this chapter is relatively standard on fluid flow. However, the emphasis is on problems of natural gas flow and two-phase flow. The problems associated with calculating vertical and horizontal flow are useful—especially the hints on how to calculate flow in such systems.

Chapter 7 • *Drilling and Completion of Wells.* Chapter 7 is an overview containing relatively concise descriptions of gas fracturing and acidizing operations. The discussion of well logging is a review of most of the various kinds of logs that are used.

Chapter 8 • *Flow in Reservoir and Adjacent Aquifer.* This is a strong chapter. It presents a discussion of the flow of gas in reservoirs. The pressure, (pressure)^2, and pseudopressure methods of general flow are discussed. The unsteady state solution for the constant terminal rate case and for the steady-state drainage radius case are discussed. In addition, there is a good discussion of the skin effect, the effect of high-velocity flow, and the well storage effects.

Chapter 9 • *Gas Well-Testing.* Another strong chapter, it begins with a good discussion of deliverability tests. The second part discusses tests for determining reservoir parameters. Examples are given of how to calculate the actual pressures. Tests for determining reservoir parameters include drawdown tests, multi-rate tests, two-rate tests, and build up tests. The discussion, though concise, is complete, and there are several examples that show how to use these particular tests to determine reservoir properties.

Chapter 10 • *Reservoir Engineering Applied to Gas, Gas / Condensate, and Gas / Oil Fields.* This survey chapter discusses determining initial estimates of oil and gas reserves using either volumetric calculations or early production history. The mechanisms of oil recovery are discussed in very general terms. The solution of the material balance equation for a reservoir is shown.

Chapter 11 • *Simulation: Field and Reservoir Performance.* This chapter and its first three sections discuss the implicit, explicit, and Crank-Nicolson numerical methods for solving the partial differential equations that approximate the flow in a reservoir. The discussion is concise and includes an example of the one-dimensional situation. There is also a brief discussion of the inverse problem.

Chapter 12 • *Conversion of Depleted Gas, Gas / Condensate Fields to Gas Storage Reservoirs.* The gas storage problem is discussed at a survey level in this chapter. There is a good description of why storage is needed and how gas is stored. A detailed case study is presented.

Chapter 13 • *Gas Storage in Aquifers.* This is an excellent chapter—the strongest in the book. It begins with procedural steps in locating and developing an aquifer storage reservoir. The discussion of locating such a reservoir is detailed, and there is a series of discussions of the measurements that are required. Predictions on the rate of bubble development or water pushback are discussed. There is a general discussion of the various studies of aquifers.

Chapter 14 • *Monitoring, Inventory Verification, Deliverability Assurance, and Safety in Storage Operations.* This chapter surveys what must be done to run a gas storage operation and represents the tremendous experience of the senior author. This chapter and the previous one are condensed from *Underground Storage of Fluids,* by Katz and Coats (1968).

Chapter 15 • *Natural Gas Liquid Recovery and Gas for the Fuel Market.* Natural gas liquids (ethane, propane, butanes, and pentanes) are recovered by refrigeration adsorption stripping or cryogenic expansion/compression.

Chapter 16 • *Storage in Salt Cavities and Mined Caverns.* The description in this chapter is narrative, explaining the attributes of such caverns and how one develops caverns. Also, there is a discussion of creating cavities by dissolving materials or leaching out the materials.

Chapter 17 • *Miscellaneous Topics.* This chapter opens with a narrative of compressed air energy storage for electric power peaking cycles. Much of the chapter discusses the design of a storage facility. It also contains calculations associated with transcontinental pipelines, geochemical identification of natural gas, superheat limit vapor explosion, and the phase behavior associated with it.

Six appendices contain data on computer programs for calculating flow, derivations of gas flow equations in reservoirs, a detailed discussion of the Peng-Robinson equation of state, equilibrium constants, and nomenclature. ❐

ChE book review

MASS TRANSFER

by J. A. Wesselingh, R. Krishna

Ellis Horwood Ltd., Market Cross House, Cooper St., Chichester, West Sussex, PO19 1EB England; 243 pages, $69.95 (1991)

Reviewed by
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This is an extremely interesting (but in many ways frustrating) short book on the use of the Maxwell-Stefan (M-S) approach for solving complicated mass transfer problems. Since the authors assume considerable familiarity with Fickian diffusion and with various separation methods, this book is appropriate for graduate students. A finite difference approximation to the differential equations is used throughout the book, and the calculations required are well within the capabilities of graduate students.

After an introductory chapter, Chapter 2 explores

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