2 Advanced Theories of Two-Phase Flow in Porous Media

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2.1 INTRODUCTION

Fluid-filled porous media are ubiquitous in many natural and industrial systems. The working of these systems is controlled and/or affected by the movement of fluids, solutes, particles, and heat through them. Examples of natural porous media and corresponding processes are the flow of oil, gas, and water in oil reservoirs; the potential mobilization of methane in gas hydrates; the flow of nonaqueous phase liquids (NAPLs) in contaminated aquifers; the storage of CO_2, nuclear waste, other hazardous wastes, and heat in the subsurface; the flow of fluids in biological tissues; and melting and metamorphism of snow. Examples of industrial porous media and corresponding processes are the drying of paper pulp, the adsorption of liquids in diapers and similar absorbing products, gas and water management in fuel cells, and the drying of foods, building materials, detergent tablets, and filters.

Many physical, chemical, and thermal processes (such as fluid flow, diffusion, capillarity, dissolution, adsorption, clogging, degradation, and swelling) occur in these materials. For the design, operation, and maintenance of porous media systems, it is extremely important to understand these processes, describe them quantitatively (by mathematical models), and compute solutions to the governing equations. One would expect that for such a vast range of highly important systems and for complex processes occurring therein, a well-founded science with deep roots in fundamental principles of physics and mechanics should have been developed. Indeed, governing equations embedded in mathematical models of complex porous media systems should originate from rigorous derivations following a systematic approach. But the main equations used in porous media models are relatively simple equations, often borrowed from other disciplines: Darcy's law for flow, Fick's law for solute transport, Fourier's law for heat transfer, and Hooke's law of elasticity