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## A Critical Review for Proper Use of Water/Oil/Gas Transfer Functions in Dual-Porosity Naturally Fractured Reservoirs—Part I

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### Abstract

Accurate calculation of multi-phase fluid transfer between the fracture and matrix in naturally fractured reservoirs is a crucial issue. In this paper, we will present the viability of the use of simple transfer functions to accurately account for fluid exchange resulting from capillary, gravity and diffusion mass transfer for *immiscible flow* between fracture and matrix in dual-porosity numerical models. The transfer functions are designed for sugar-cube or match-stick idealizations of matrix blocks.

The study relies on numerical experiments involving fine-grid simulation of oil recovery from a typical matrix block by water or gas in an adjacent fracture. The fine-grid results for water-oil and gas-oil systems were compared with results obtained with transfer functions. Both in water and gas injection, the simulations emphasize the interaction of capillary and gravity forces to produce oil depending on the wettability of the matrix.

In gas injection, the thermodynamic phase-equilibrium, aided by gravity-capillary interaction and to a lesser extent by molecular diffusion, is a major contributor to interphase mass transfer. For *miscible flow* the fracture-matrix mass transfer is less complicated because there is no capillary forces associated with solvent and oil; nevertheless, gravity contrast between solvent in the fracture and oil in the matrix creates convective mass transfer and drainage of oil.

Using the transfer functions presented in this paper, fracture and matrix flow calculations can be decoupled and solved sequentially—reducing the complexity of the computation. Furthermore, the transfer function equations can be used independently to calculate oil recovery from a matrix block.

### Introduction

Naturally fractured reservoirs contain a great amount of the known petroleum hydrocarbons worldwide and hence are an important source of energy fuels. However, the oil recovery from these reservoirs has been rather low. This low level of oil recovery points to the need for accurate reservoir characterization, realistic geological modeling, and accurate flow simulation of naturally fractured reservoirs to determine the locations of bypassed oil.

Reservoir simulation is the most practical method of studying flow problems in porous media when dealing with heterogeneity and the simultaneous flow of different fluids. In modeling fractured systems, a dual-porosity concept is typically used to idealize the reservoir on the global scale. In the dual-porosity concept, the bulk of the fluid transport takes place at high velocities in the fractures from one grid cell to another irrespective of flowing phase. On the other hand, in two- or three-phase flow, there is usually a local exchange of fluids between the fractures and the adjacent matrix at comparatively low velocities. The issue of fluid velocities is very critical in naturally fractured reservoirs because, in multi-phase flow, typically water or gas can move rapidly in the fractures and surround the matrix blocks partially or totally. Once a matrix block is surrounded partially or totally by a particular fluid, then transfer of fluid phases and components takes place between the fracture and matrix, which is the focus of this paper. In particular, deciphering the exchange mechanisms and describing the pertinent equations of mass transfer constitute the heart of this paper. Similar issues are relevant to any variants of the dual-porosity concept, such as the triple-porosity, irrespective of the idealization concept.

### Physical Perspective

First, let us consider a naturally fractured reservoir containing a single-phase fluid, such as gas. For this case, the reservoir is produced by fluid expansion via production wells. The production mechanism is rather simple in that the producing well creates a pressure gradient in the fractures connected to the well, which, in turn, fractures create a pressure drawdown on the adjacent matrix to create matrix flow. In this scenario all connected fractures play a role in bringing gas to the wells. In fact, the early models of Barenblatt, et al (1960) and Warren and Root (1962) pertain to this mechanism. *We should note that, in these publications, the driving force for*