A set of relative permeability relations for simultaneous flow of steam and water in porous media were obtained from a steady state experiment. The experiment was conducted under conditions that minimize most of the difficulties encountered in the past for similar experiments. A high resolution X-ray CT scanner was used to obtain three-dimensional porosity and saturation distributions during the experiment. Pressure and temperature data were collected with the use of several pressure transducers and thermocouples located at various locations along the core. Relative permeability values were calculated over the core lengths identified as having flat saturation profiles. These aspects constitute a major improvement m the experimental method compared to those used in the past. The experimental results showed the relative permeability to both steam and water vary linearly with saturation, in contrast to those obtained by Corey (1954) for gas/water flow experiments. Comparison of the saturation profiles measured by the X-ray CT scanner during the experiments shows good agreement with those predicted by numerical simulation. To obtain results that are applicable to general flow of steam and water in porous media, similar experiments should be done at higher temperature and with porous rocks with different wetting characteristics and porosity distribution.

Introduction

In general, the concept of relative permeability is an attempt to modify Darcy's law for single-phase flow in porous media in order to account for simultaneous flow of multi phases. In this description the flow of each phase is governed by the individual microscopic pressure gradients and by the fraction of the overall permeability that is associated with it. This fraction, normally expressed as a fraction of the medium's permeability to a single-phase fluid, is called the relative permeability. Relative permeability relations have been traditionally expressed as a function of saturation principally because it was believed that they depended on the pore volume occupied by the fluids (Hassler, 1944). While a great number of experiments have shown this to be true, a number of other experiments have shown that relative permeability depends also on several other parameters such as interfacial tension, wetting characteristics and viscosity ratios of the flowing fluids etc. (Fulcher et al., 1983; Osoba et al., 1951). In addition it is necessary to define residual saturations which normally indicate the lowest saturation value for a given phase to become mobile. The curves and the residual saturations together define the relative permeability relations (Corey, 1954; Brooks and Corey, 1964).

For most applications in petroleum engineering involving the flow of oil and water as in water flooding and the flow of oil and gas as in gas injection, the relative permeability relations are well known and determined routinely from laboratory experiments (Osoba et al., 1951). However, for the flow of steam and water or for the general case of multi component multi phase flows these relations are not well known. A look at previous literature shows that there is a significant discrepancy and inconsistency in the results previously obtained (Verma, 1986; Sanchez, 1987; Clossman and Vinegar, 1988). The main difficulties encountered in the previous experiments, as we show later in this paper, have been mainly due to inaccurate measurements of fluid saturations and inappropriate assigninent of pressure gradients to the individual phases.

Techniques involving analysis of enthalpy transients from producing geothermal fields have been proposed to infer relative permeability relations (Grant, 1977; Sorey et al., 1980; Horne and Ramey, 1978).