Solution Mining Research Institute Fall 2020 Virtual Technical Conference

22-24 SEPTEMBER 2020

RELATIVE PERMEABILITIES FOR TWO-PHASE FLOW THROUGH WELLBORE CEMENT FRACTURES

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Abstract

Multiple fluids are likely to exist in fractures and flow paths associated with leaky wellbores, including liquids (e.g., crude oil) and gases (e.g., gas ex-solved from liquid and/or nitrogen from MIT tests). These fluids occupy and move through different portions of the pore spaces within the fractures depending on many factors, including fluid properties, fracture size, and amount of the different fluids. Upward leakage of any phase through the fracture can contaminate water-bearing formations, create hazardous surface conditions, and compromise the functionality of the wellbore. When there are multiple fluid phases present, there is no straightforward way to estimate the individual or total leakage rate or permeability by monitoring any one phase. Our study investigates the relationship of the liquid–gas relative permeabilities for representative variable-aperture wellbore cement fractures. To measure the relative permeability of each phase, flow tests were conducted where both fluids were flowing simultaneously through a fractured wellbore cement specimen. The flow experiments were conducted under a range of confining stresses and flow velocities using nitrogen and silicone oils of different viscosities in a specially designed pressure vessel. The sum of gas and liquid relative permeabilities was found to be less than one under all conditions, which indicates that the presence of one phase affects the permeability of the other phase, and vice versa. These results indicate that the two-phase flow behavior in leaky wellbores is not well represented by the simplest of conceptual models often used by industry. The factors affecting the relationship between the relative permeabilities are discussed.

Keywords: Caverns for Liquid Storage, Two-Phase Flow, Leaky Wellbore, Relative Permeability, Cement Fracture.