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Thermal Analytical Solution for Rate Transient Analysis

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Pressure-induced temperature transient analysis has emerged recently with the downhole temperature monitoring techniques to characterize the reservoir. In this work, we develop analytical approaches and solutions to model the temperature signals associated with variable rate production of slightly compressible fluid and apply it to several field temperature measurements to characterize the reservoir. The analytical solution presented in this paper is more applicable for field application compared to previous temperature transient analytical solutions assuming constant rate production.
This model is derived from the single phase energy balance equation coupled with transient rate and pressure behaviors. Applying the temperature transient analytical solution under boundary dominated flow, the effect of rate variability on temperature signals is well understood and analyzed with the temperature profiles. Various super-position and material balance time procedures are applied for different production scenarios. Simple procedures to apply this model are provided, which present a convenient way to predict the temperature profile. In addition, we provide thermal inversion procedures to characterize the reservoir by evaluating its permeability, porosity, drainage area, and reservoir shape.
The temperature profiles obtained from the analytical solution shows good agreement with those from numerical simulation and are sensitive to total compressibility and reservoir permeability, thickness, and boundary. Sensitivity analyses of temperature profiles are performed on reservoir thickness, permeability, outer boundary radius, total compressibility, fluid specific gravity, specific heat, and viscosity. The early time temperature profiles are induced by pressure transient and followed by the late time effect of boundary dominated flow. With adequate knowledge of other reservoir properties, detailed procedures are demonstrated and can lead to the interpretations of permeability, reservoir boundary, and damaged zone permeability. Even with no prior knowledge of other reservoir properties, simplified procedures reveal several groups of properties. Several field temperature measurements are applied with the developed solution to estimate reservoir properties. The estimations are compared with available properties acquired from other methods to explore the practical purpose of this model. The analytical solution presented in this paper is more applicable for unconventional reservoir characterization application compared to previous analytical solutions for temperature transient analysis.

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