# Temperature Prediction Model for a Producing Horizontal Well

## Intro

* To perform an inference about the amount and types of fluids entering horizontal well sections, a temperature model is developed in the current work.
* The distinguishing aspect of the model is that it accounts for subtle thermal energy effects including fluid expansion, viscous dissipative heating and thermal conduction.
* Reservoir inflow and wellbore flow are coupled by modeling the reservoir as multi-segmented reservoirs in which the direction of flow in the reservoir is perpendicular to the wellbore
* Inflow temperature causes the slope of the wellbore temperature profile to change notably, depending on the flow rates and types of fluid entering
* The information of amount and types of fluids entering in the wellbore is essential for reservoir and well management
* This study focuses only on temperature data in a horizontal well that is producing under steady-state flow or for a sufficient long-time
* There are three main motivations to study temperature profiles in horizontal wells during production:
  + Advancement of DTS
  + Past successes of temperature measurement and interpretation in some applications
  + Proliferation of horizontal wells as driven by continued advances in drilling technology
* DTS employs a thin glass fiber optical cable installed along the entire length of the well.
* Use of DTS can be cost effective and less risky than conventional production logging for horizontal wells
* DTS enables continuous monitoring of a well
* Transform temperature data into flow information which is important for reservoir management
* Temperature logs have been used successfully in vertical wells to locate gas entries
* Horizontal wells have become a common production technique for oil and gas recovery. The flow geometry of horizontal wells is much more complex than vertical wells because the flow is constrained by the horizontal reservoir boundaries
* Geothermal temperatures along horizontal wells are almost constant because it is mainly a function of depth. So, it is crucial to include subtle thermal energy effect; heat convection, fluid expansion, viscous dissipation and thermal conduction.
* Temperature logging is probably the oldest production log
* Fluid flow in a reservoir can be approximated as an isenthalpic flow, during production, the Joule-Thompson effect is a dominant factor causing the inflow temperature of the fluid to be different from the geothermal temperature at that depth.
* Great reference in temperature logging: Hill (1990)
* Temperature well logs can be used to locate gas entries, top of cement, detect casing leaks and channels, estimate flow rate,
* Use of temperature log to estimate well flow rate – Ramey model (1962): incompressible fluid, fluid loosing heat while going upward. It is possible to relate temperature measurement to flow rate profile in vertical wells

Chapter 2

* A productivity model that describes the pressure distribution in a reservoir is necessary to couple with an energy balance. The semi-analytical model for a single-phase flow in anisotropic reservoir is showed
* The model for the reservoir derived from conformal mapping is employed in the work ( It describes the pressure distribution on the reservoir
* Wellbore flow model: predict pressure and temperature behavior along the well
  + We can’t neglect the pressure drop along the well like we do for vertical ones
  + Couple an inflow temperature model with a non-isothermal wellbore flow model (the last developed by Yoshioka) in order to predict temperature distribution inside the well. The Yoshioka’s model is a homogeneous one. For temperature, it includes convection and Joule-thompson effects

Chapter 3 – Analytical Temperature model

* Develops an analytical temperature model that couples reservoir and wellbore flows
  + Gravity effects aren’t considered and the geothermal temperature is constant
  + The geometry that the model is based has no-flow boundaries on top and bottom and it has prescribed pressure on the laterals
  + An inflow model considering two flow regions, one radial and the other linear is used.
  + Energy and mass balance can be solved analytically for a single-phase flow under steady-state conditions( the flow would be pseudo-steady if the reservoir boundaries were all no-flow)
* Reservoir
  + Mass balance ( div(rho V) = 0 ) – (Lake, EOR)
  + Darcy’s law - (Lake, EOR)
  + Energy balance ( Stanley, Chemical Engineering thermodynamics): The equation accounts for heat convection, conduction, viscous dissipation and Joule-Thompson effect
* Approximate temperature model: estimative to the real temperature field considering that there is no heat exchange between the wellbore and the reservoir
* A simplified analytical inflow model is solved to obtain the initial guess for temperature distribution in the wellbore. Next, the wellbore temperature is solved by the non-isothermal wellbore model. Next the inflow temperature is recalculated by the analytic temperature model which accounts for heat conduction at the sandface. The process is repeated until it is converged.
* Temperature profiles are used to infer inflow profiles, to identify water or gas entry and to locate no-flow sections
* For the example in 3.5.2 the wellbore flow effects are negligible because the wellbore diameter is too large (6 inches).
* In the water zone the temperature decreases
* Temperature profiles can identify no-flow zones, knowing its location helps tell where to perform a well stimulation like acidizing, fracturing…

Chpater 4 – Numerical Temperature Model of Two-Phase Flow

* The model developed in chapter 3 predicts that water enters at a lower temperature than oil in the wellbore because of its larger heat capacity. This prediction is in conflict with field observations (Foucault, 1994)
* This chapter studies temperature behavior in a horizontal well subjected to bottom water drive.
* The new model numerically solves mass and energy balances for two-phase flow both in the reservoir and wellbore. The fluid properties vary with temperature and pressure while flowing, the key difference from typical thermal oil recovery simulators is that this model includes temperature changes caused by pressure drops (Joule-thompson model)