Parametric Study of Heavy Oil Recovery by Electromagnetic Heating

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Introduction: An oil-gas two-phase linear flow Electromagnetic Heating (EMH) is presented with COMSOL. Comparison to the Electrical Resistance Heating (ERH) simulated by STARS is also conducted. Parametric study shows that cumulative oil production obtained by EMH is higher than what is achieved by single well Steam Assisted Gravity Drainage (SW-SAGD).

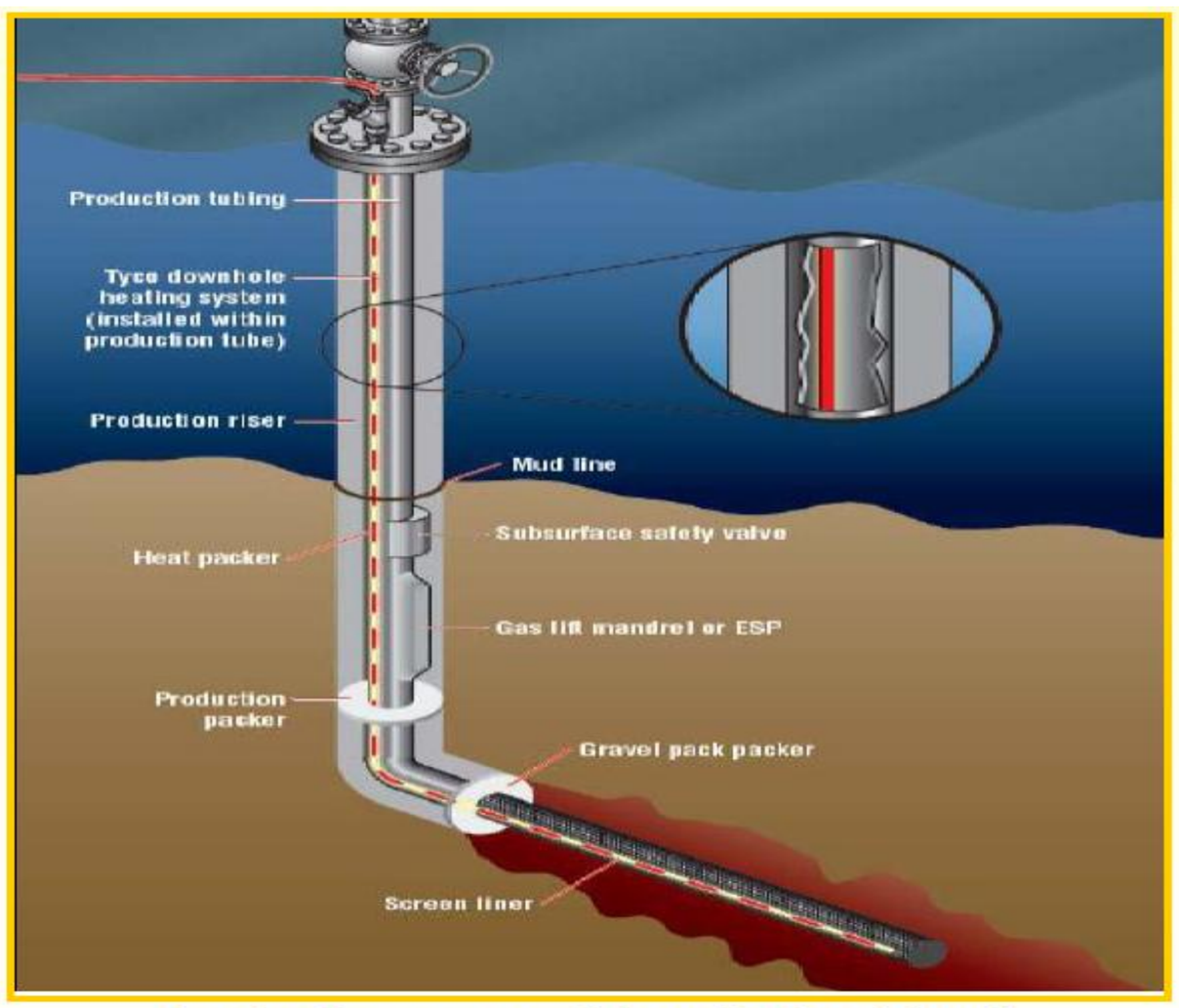

Figure 1. Application of electrical heating system on a vertical well

Results:

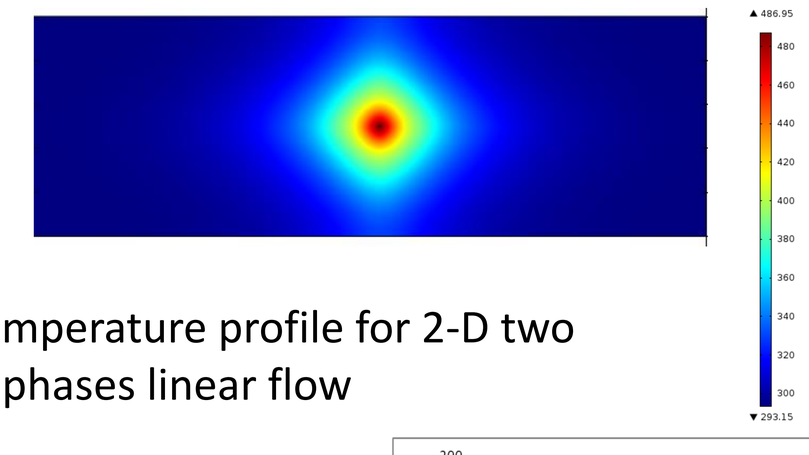

Figure 2. Temperature profile for 2-D two phases linear flow

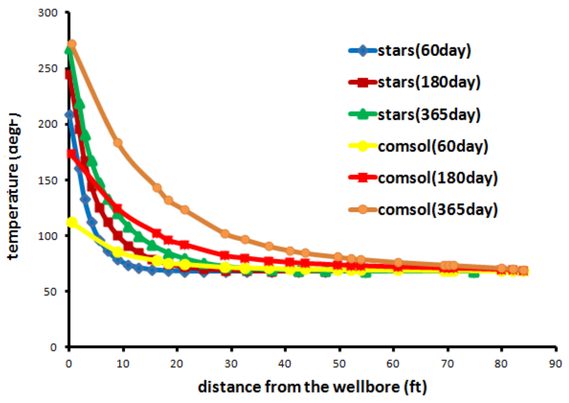

Figure 3. Comparison of EMH and ERH performance under same energy input

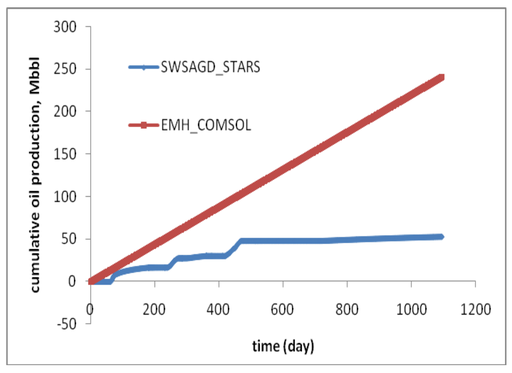

Figure 4. Cumulative oil recovered for EMH and SW-SAGD for the thin-zone (7m) reservoir

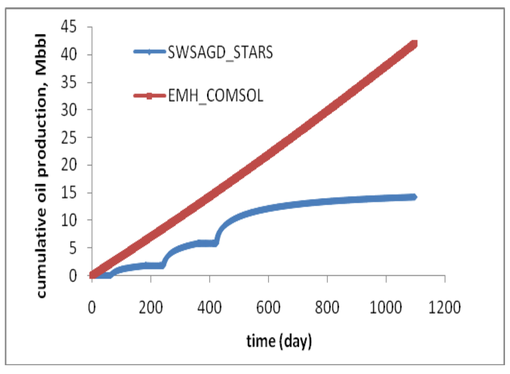

Figure 5. Cumulative oil production for EMH and SW-SAGD for the low permeability reservoir

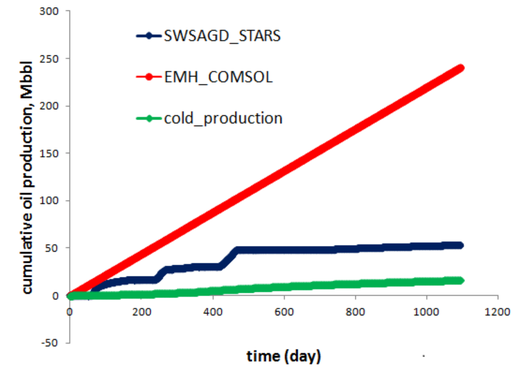

Figure 6. Cumulative oil recovered in Mbbl for EMH, cold production and single well SAGD

Computational Methods: Linear flow can be observed during the early time period when the horizontal well or fracture exist.

$$\frac{\partial(\rho_w s_w)}{\partial t} + \nabla\bullet[-\rho_w \frac{k_{rw}k_{abs}}{\mu_w}\nabla(p_w + \rho_w gD)] = 0$$

$$\frac{\partial(\rho_{nw} s_{nw})}{\partial t} + \nabla\bullet[-\rho_{nw} \frac{k_{rnw}k_{abs}}{\mu_{nw}}\nabla(p_{nw} + \rho_{nw} gD)] = 0$$

$$C_w = \frac{\partial s_w}{\partial h_c} = \rho_{H_2O} g \frac{\partial s_w}{\partial p_c}$$

$$\rho_m C_{p,m} \frac{\partial T}{\partial t} + \nabla\bullet(-k_m \nabla T) = Q_h$$

Initial and Boundary Condition:

$$at\ t = 0\ \ p_w = \rho_w g(thick - D) - p_{c,\text{int}}$$

$$at\ t = 0\ \ p_{nw} = \rho_w g(thick - D)$$

Conclusions: EMH can be used as an alternative to steam injection, and yields better recovery factor especially for thin-zones, low-permeability and extra-heavy oil reservoirs.

References:

1. Diaz-Viera, M.A, Lopez-Falcon, D.A, Moctezuma-Berthier, A. and Ortiz-Tapia, A, COMSOL Implementation of a Multiphase Fluid Flow Model in Porous Media, Proceedings of the COMSOL Conference 2008 Boston (2008)
2. Carrizales, M., and Lake, L.W., Two-Dimensional COMSOL Simulation of Heavy-Oil Recovery by Electromagnetic Heating, Presented at the 2009 COMSOL Conference held in Boston, Massachusetts, USA (2009)