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Introduction

- Most geothermal power plants use hot water/steam sources; producing from dry rock require water injection
- Our closed loop model uses production and injection tubing
- Water doesn’t invade the rock
- Formation isn’t contaminated

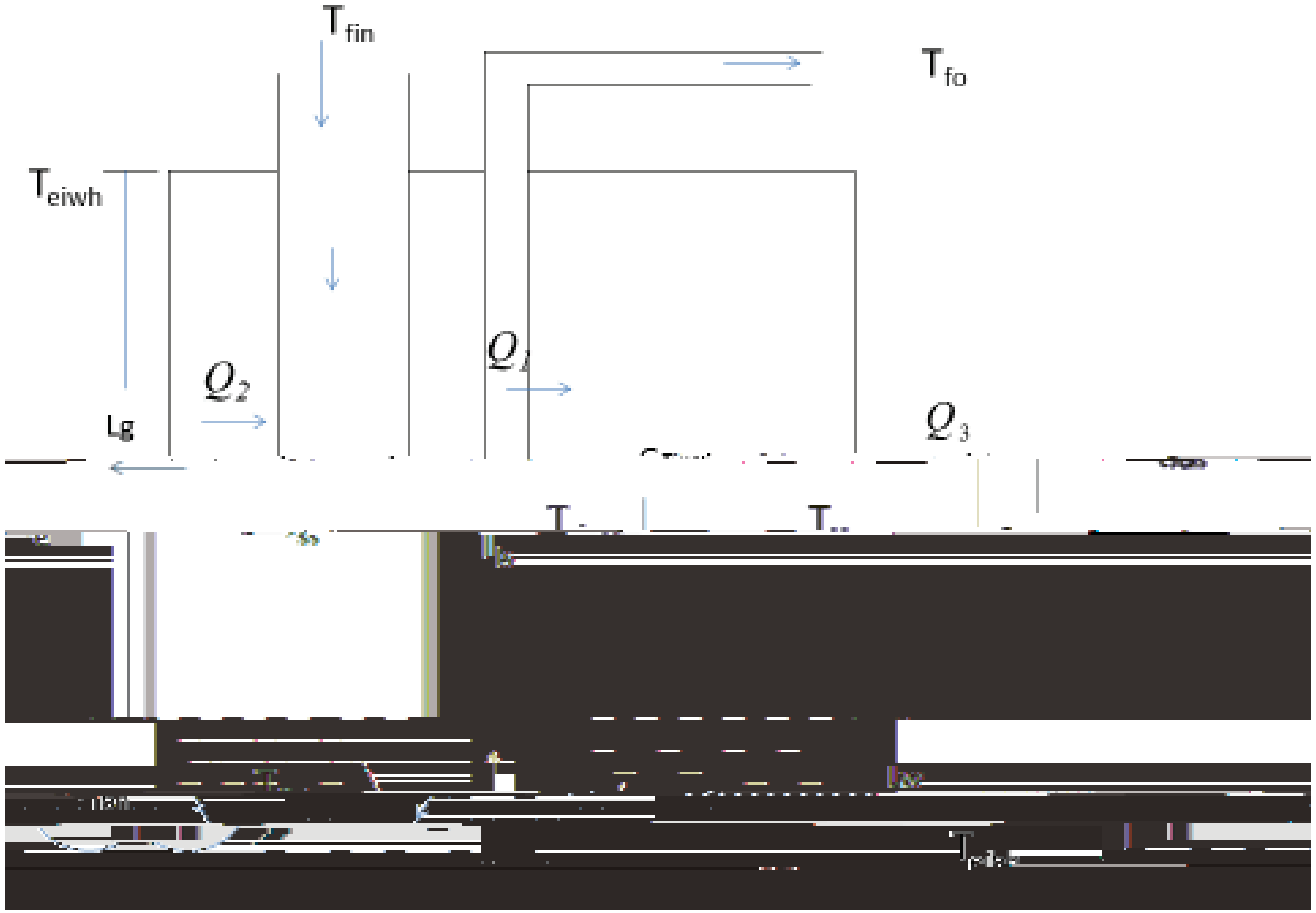


Fig: Schematic of the wellbore

L_g= height of the wellbore above the water level

L_w= height of water

ls= long string

ss= short string

Theory

Wellbore has two sections

Gas Section:

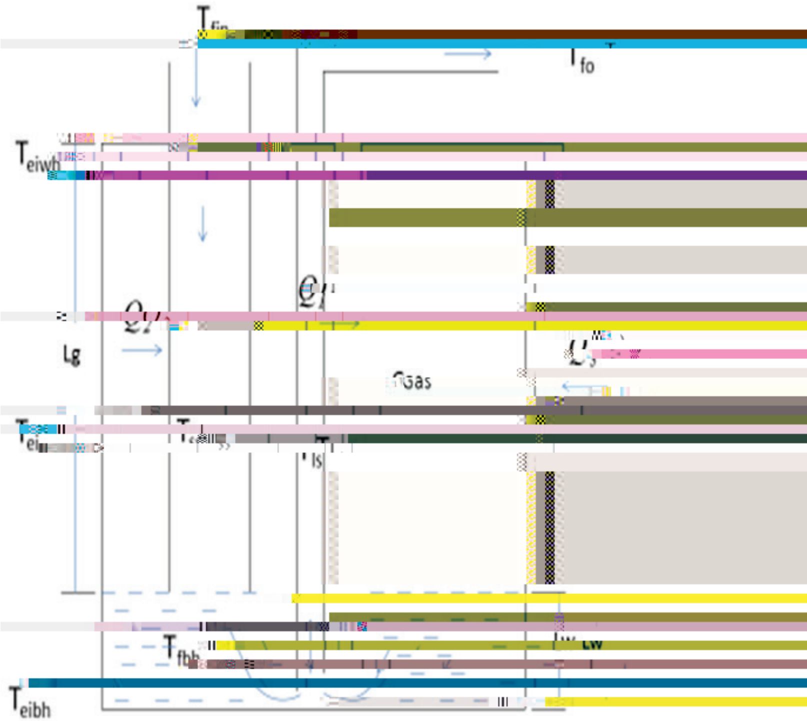
Prod. string exchange heat with annulus:

$$_1 \quad 2 \qquad - $$

Injection string heat from gas in annulus:

$$_2 \quad 2 \qquad - $$

U = Overall heat transfer coefficient



- Fluid in the tubing moving up
- Annulus fluid moving downward
- Heat exchange between the

and the fluid annulus

Liquid Section:

- Fluid in the tubing moving up
- Annulus fluid moving downward
- Heat exchange between the annulus and the fluid:

$$2 \qquad\qquad -$$

Governing Eq.

$$\frac{\mathrm{d}T_{ls}}{\mathrm{dz}} = \left(T_{ls} - T_a\right)\frac{2\pi r_{ls} U_{ls}}{c_{pls} w_{ls}} - \frac{g \sin\theta_G}{c_{pls}} + \phi_{ls}$$

$$\frac{T_{ss}}{z} \qquad \left(T_a \quad T_{ss}\right)\frac{r_{ss}\theta U_{ss}}{c_{pss} w_{ss}} \quad \frac{g \qquad\quad {}_{G}}{c_{pss}} \qquad\qquad {}_{ss}$$

Boundary Conditions

- T_{water} @ bottomhole same for annulus and the producing string;

Solution

$$T_{ss} = d_1 c_1 e^{\lambda_1 z} + d_2 c_2 e^{\lambda_2 z} + d_3 z + d_4$$

$$T_a = d_1 c_1 e^{\lambda_1 z}\left(1 + \frac{w c_{pss} \lambda_1}{2\pi r_{ss} U_{ss}}\right) + d_2 c_2 e^{\lambda_2 z}\left(1 + \frac{w c_{pss} \lambda_2}{2\pi r_{ss} U_{ss}}\right) + d_3 z + d_4 - \frac{w c_p}{2\pi r_{ss} U_{ss}}\left(\phi_{ss} - \frac{g \sin \alpha}{c_{pss}} - d_3\right)$$

$$T_{ls} = \alpha e^{\lambda_1 z} + \beta e^{\lambda_2 z} + g_G \sin\theta\, z + B'' g_G \sin\theta + T_{es} + D'$$

$$T_a = (1 - \lambda_1 B')\alpha e^{\lambda_1 z} + (1 - \lambda_2 B')\beta e^{\lambda_2 z} + g_G \sin\theta\, z + T_{es}$$

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Fig: Fluid temperature in three conduits (q=1000 gpm and insulation 0.5 inch)

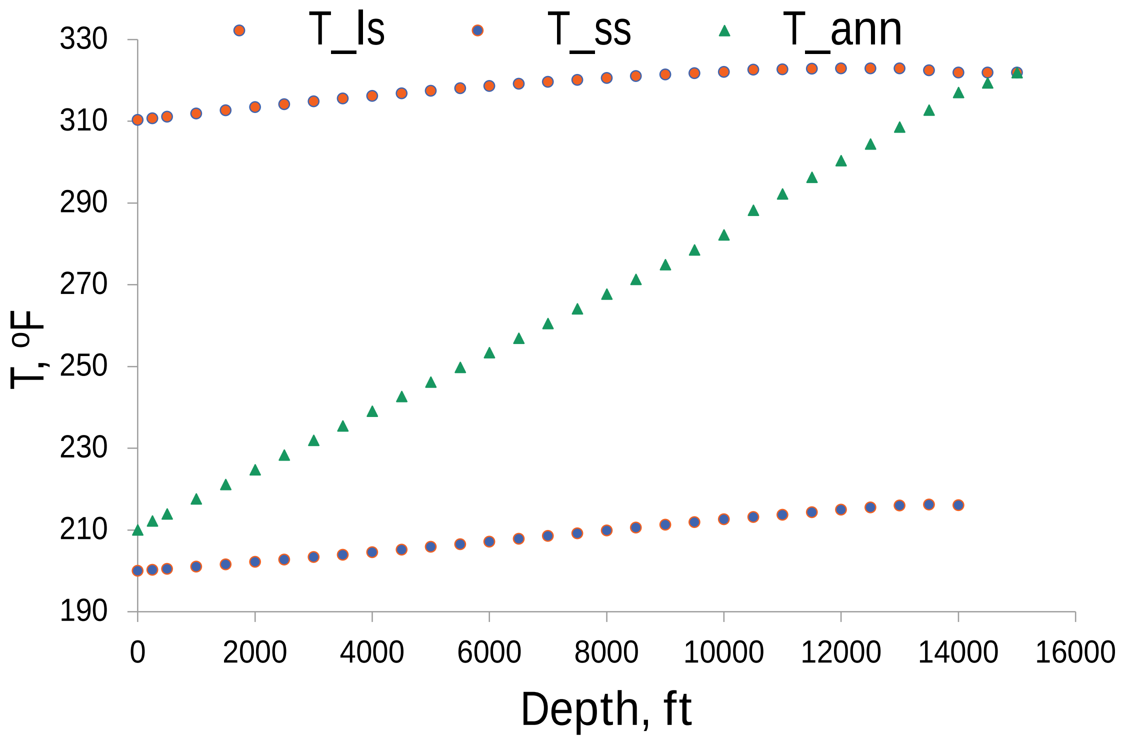


Fig. Fluid temperature in three conduits at q=1000 gpm and N_2 depth=14000 ft

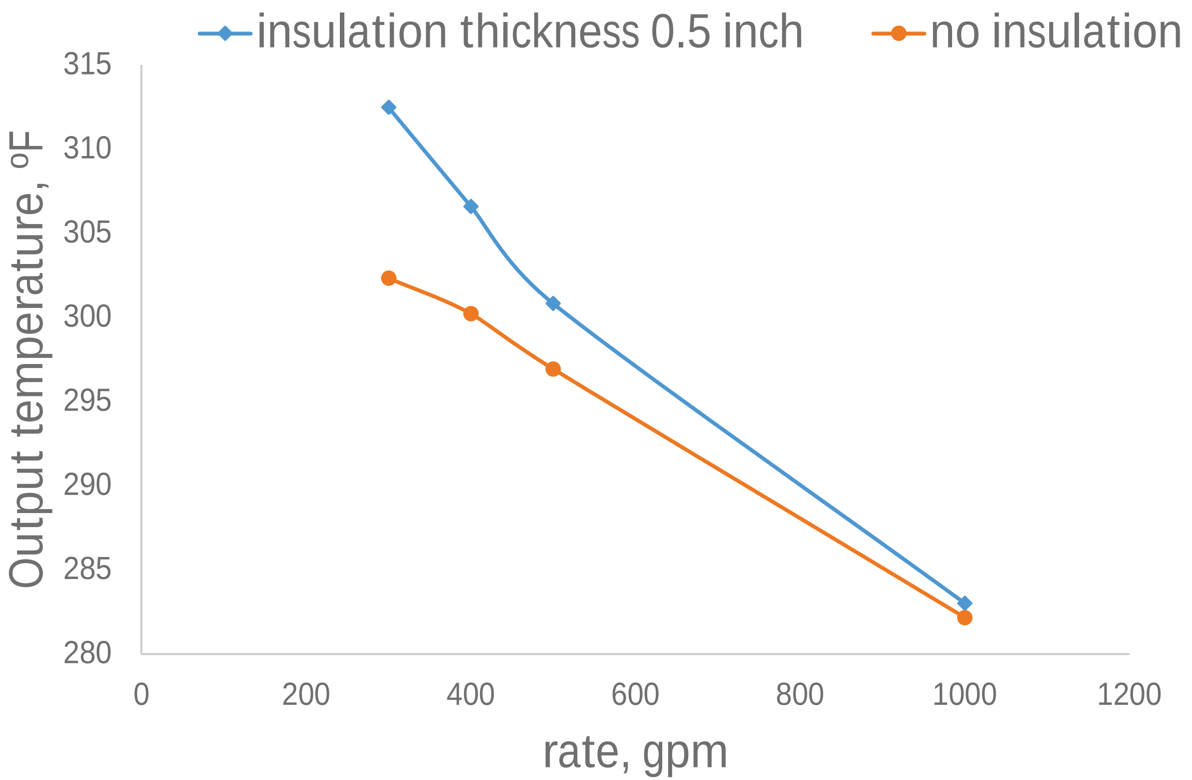
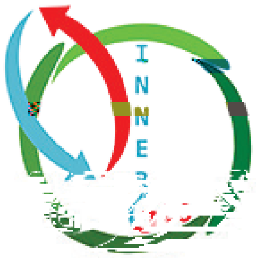


Fig: Production temperature at the surface



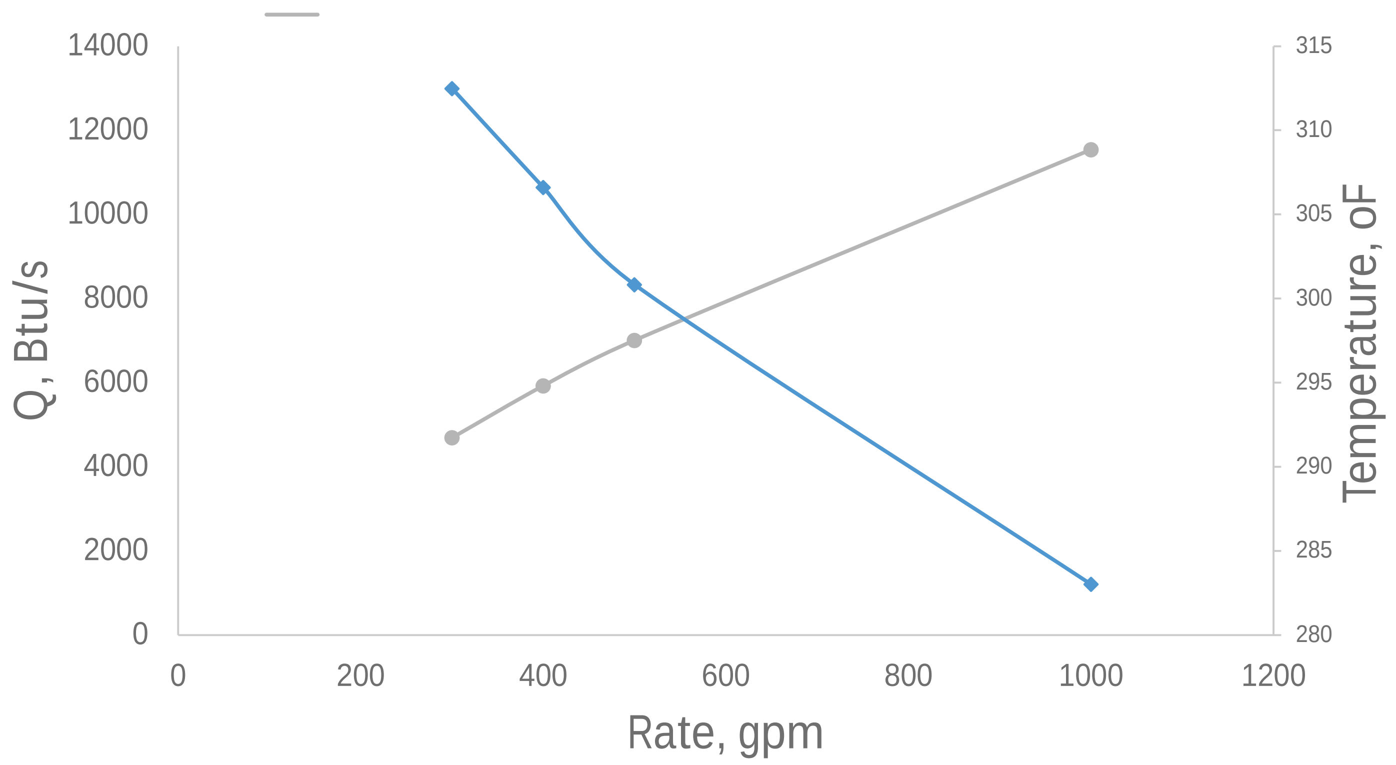


Fig: Power and Output Temperature with different rates

Conclusion

- At all flowrates, increasing the Nitrogen coverage increases fluid temperature at the wellhead
- The inclination of Tann curve changes as we move from a gas filled annulus to a water filled one
- As production rate increases, Temperature rise decreases for both insulated and uninsulated cases