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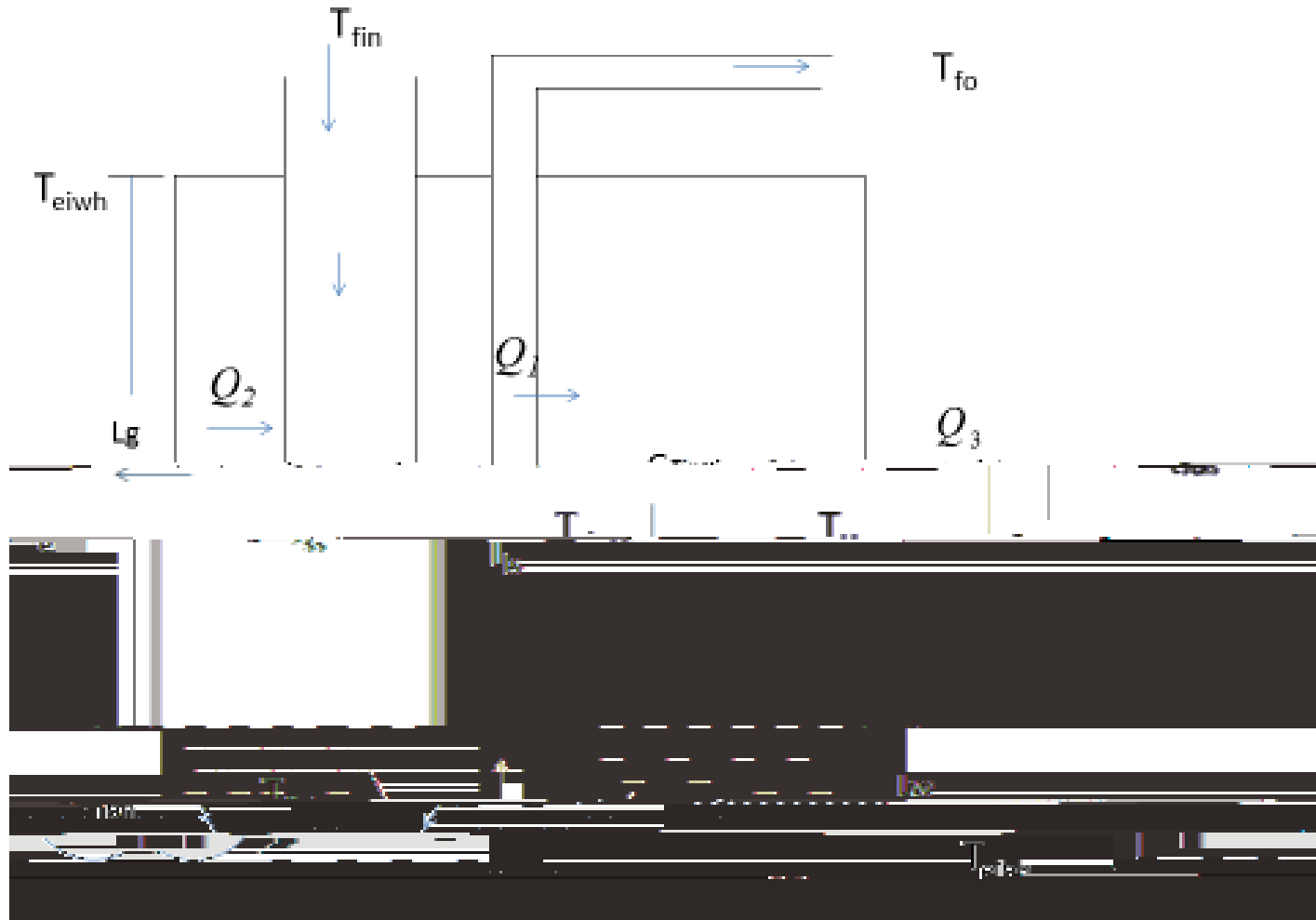


# Introduction

- 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







$L_g$  = height of the wellbore above the water level

$L_w$  = height of water

ls = long string

ss = short string

Fig: Schematic of the wellbore



# Theory

Wellbore has two sections



# Gas Section:

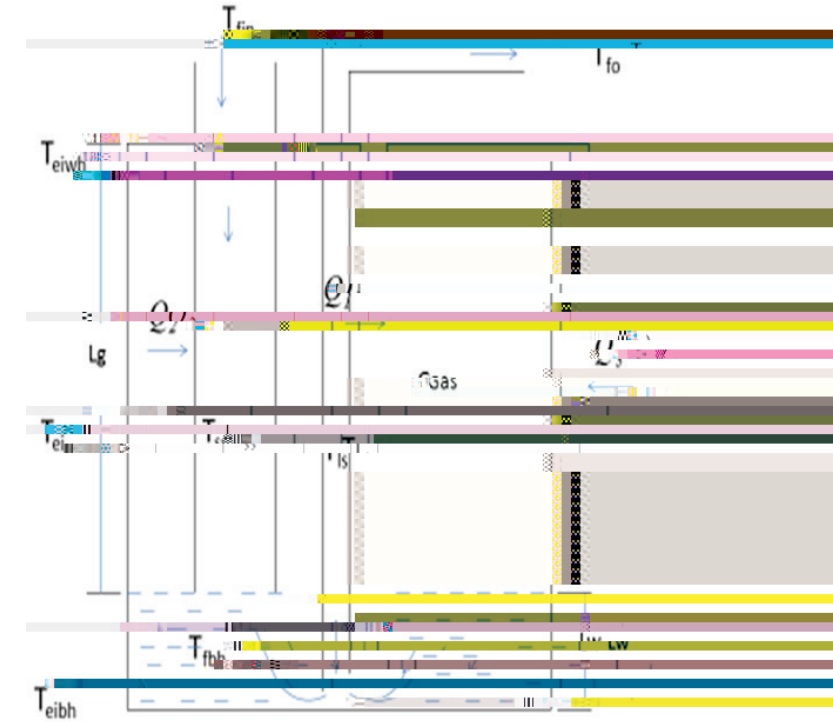
Prod. string exchange heat with annulus:

$$1 \quad 2 \quad -$$

Injection string heat from gas in annulus:

$$2 \quad 2 \quad -$$

$U$  = Overall heat transfer coefficient



## Liquid Section:

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

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- Fluid in the tubing moving up
- Annulus fluid moving downward

- Heat exchange between the



# Governing Eq.

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

$$\frac{T_{ss}}{z} = (T_a - T_{ss}) \frac{r_{ss} \theta U_{ss}}{c_{pss} w_{ss}} - \frac{g}{c_{pss}} \quad ss$$





# Boundary Conditions

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

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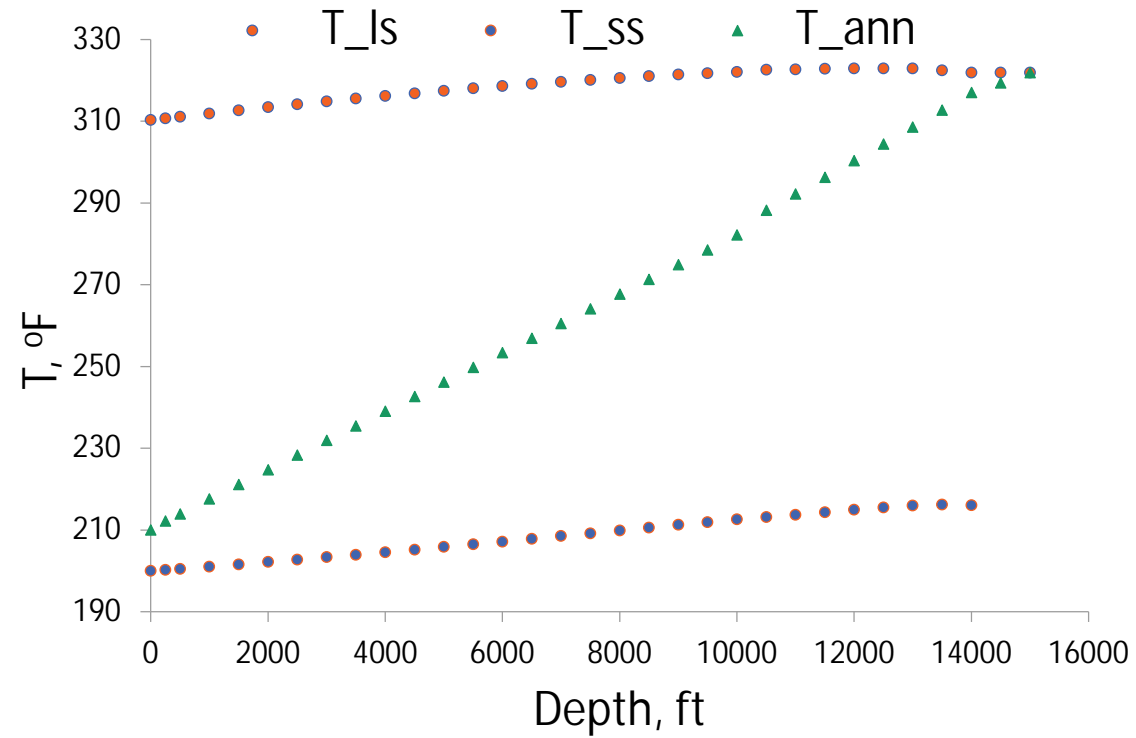
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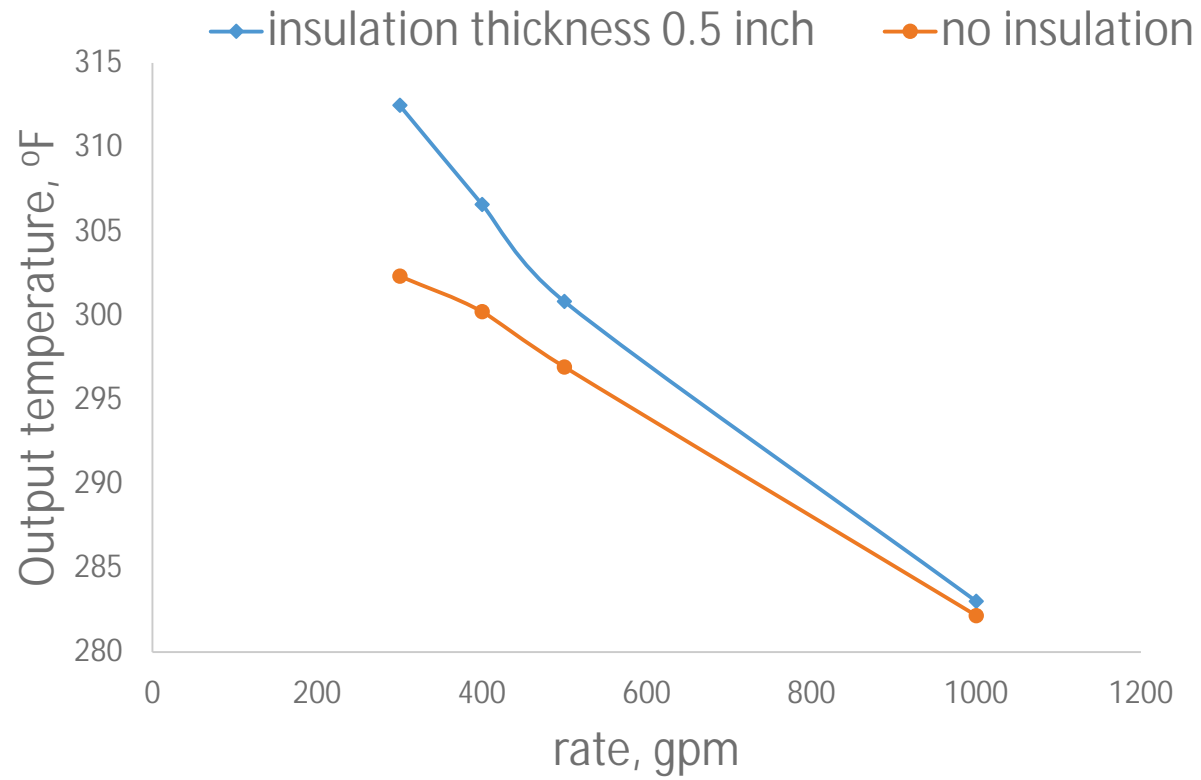
**Fig: Fluid temperature in three conduits (q=1000 gpm and insulation 0.5 inch)**





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

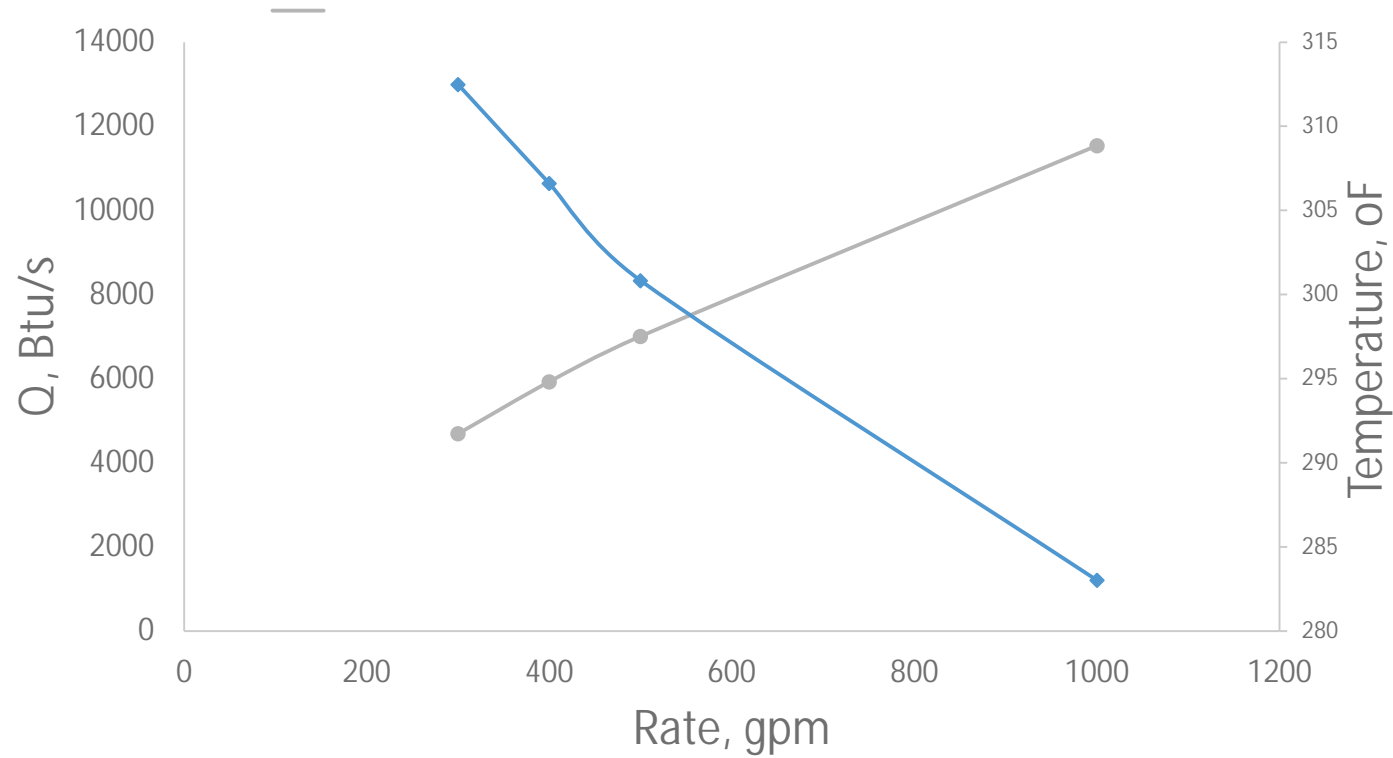




**Fig: Production temperature at the surface**







**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

