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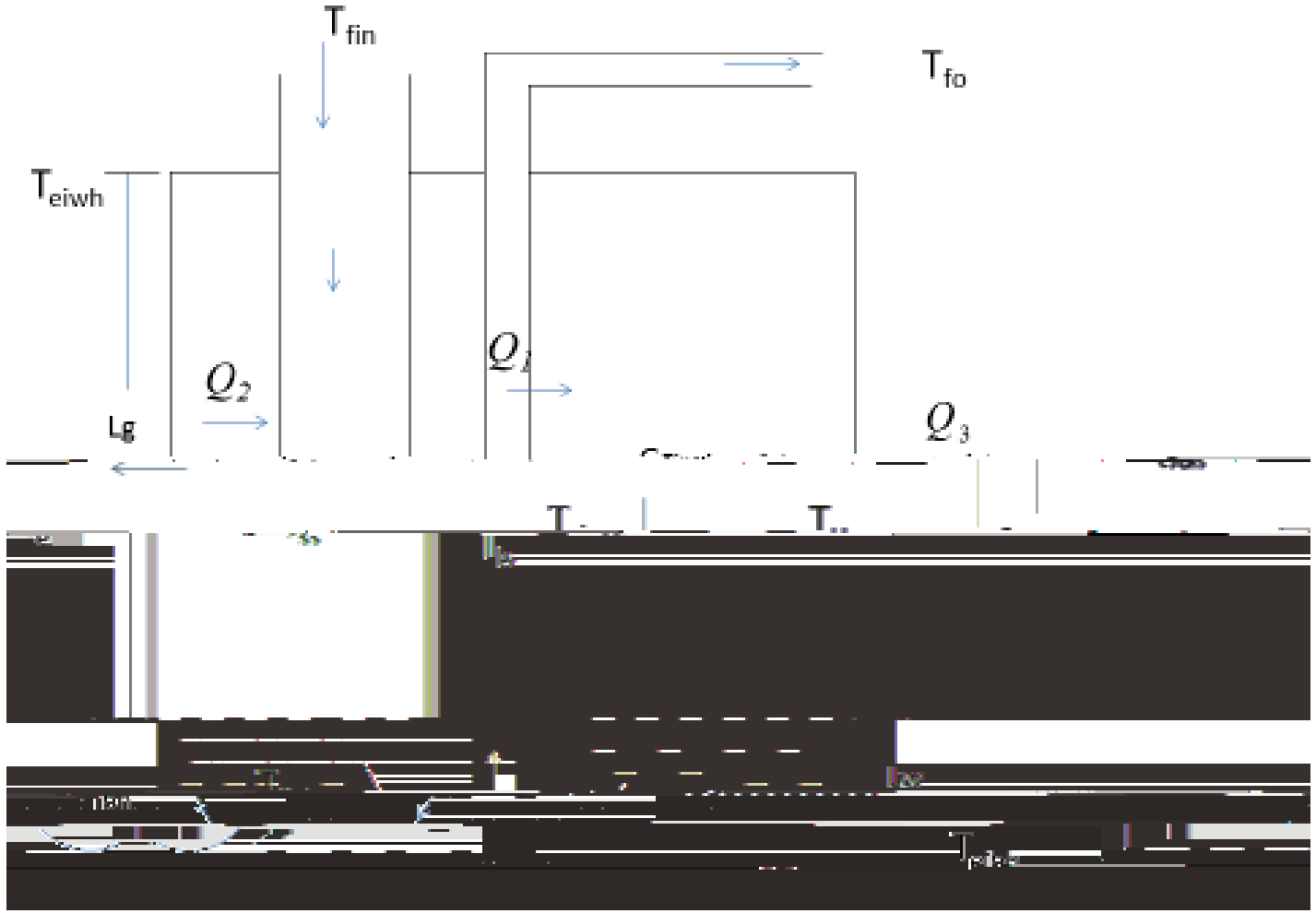


Fig: Schematic of the wellbore

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:

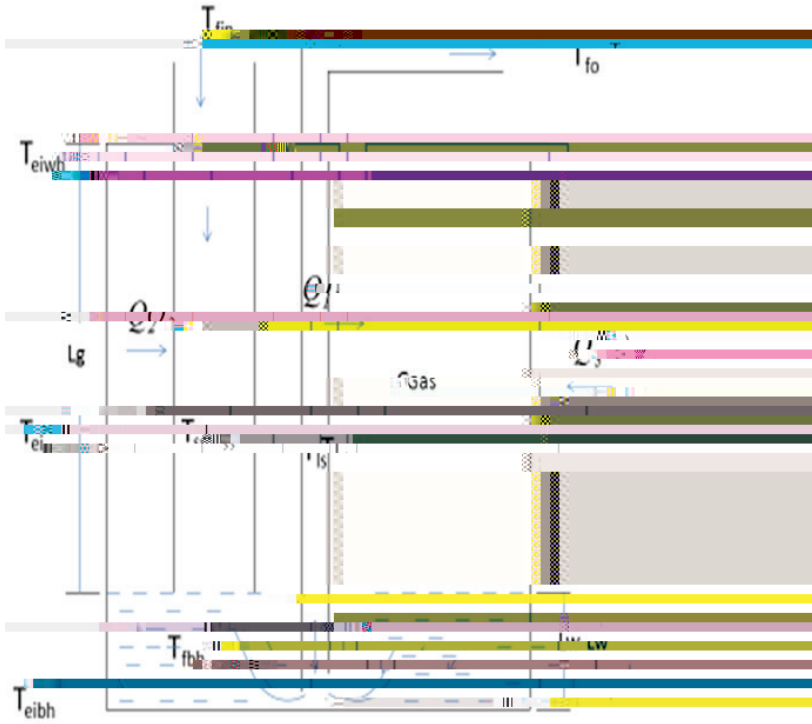
Prod. string exchange heat with annulus:

$$_{1} \quad 2 \qquad \qquad -$$

Injection string heat from gas in annulus:

$$_{2} \quad 2 \qquad \qquad -$$

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:

2 –

Governing Eq.

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

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

Boundary Conditions

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

Solution

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

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

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

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

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

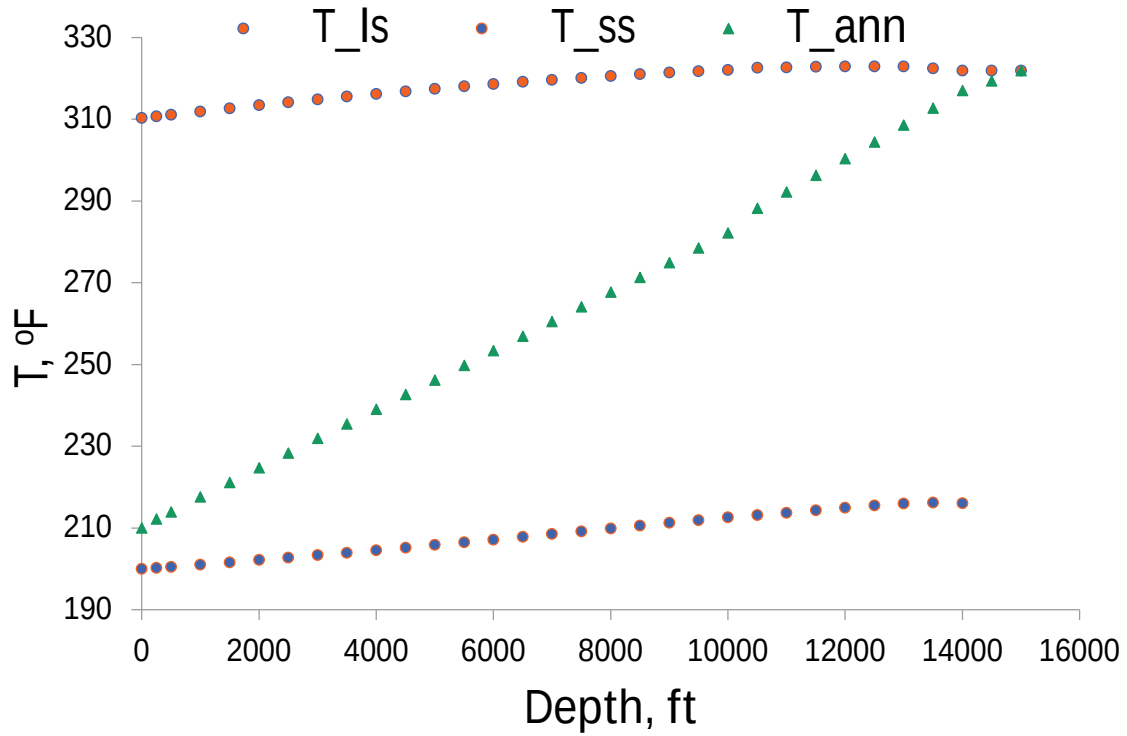

Fig. Fluid temperature in three conduits at q=1000 gpm and N_2 depth=14000 ft

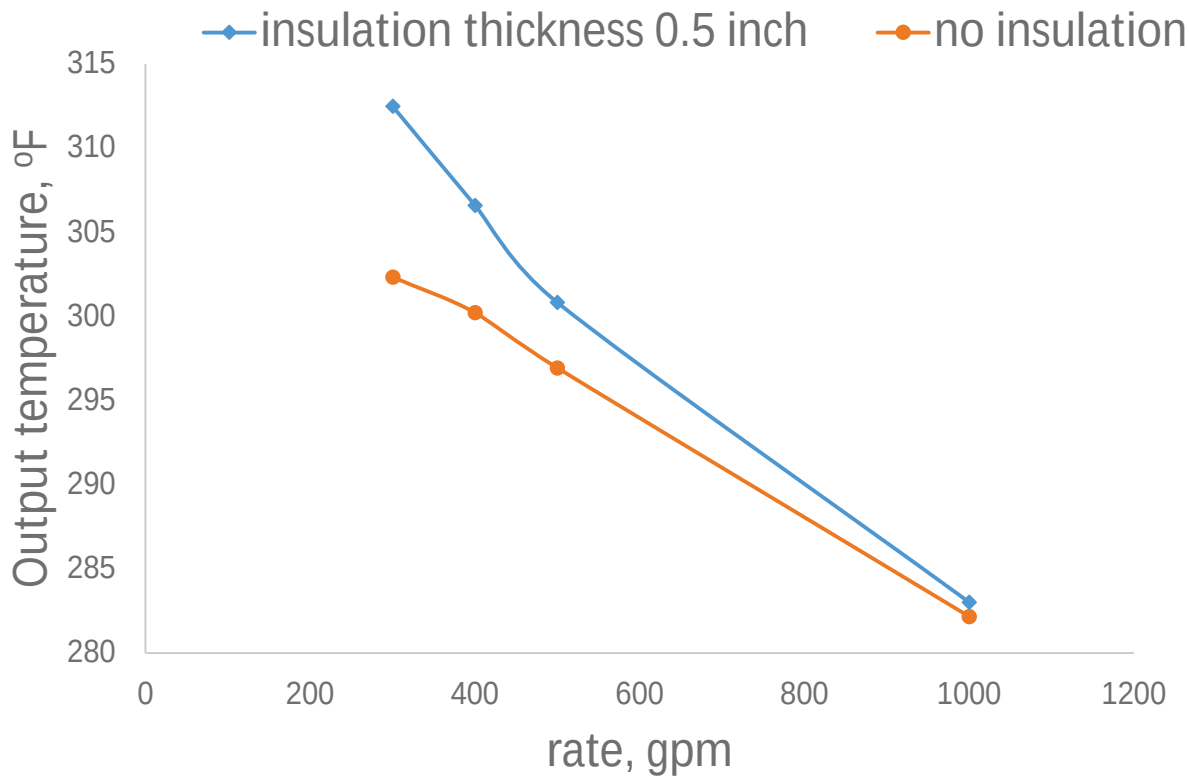

Fig: Production temperature at the surface

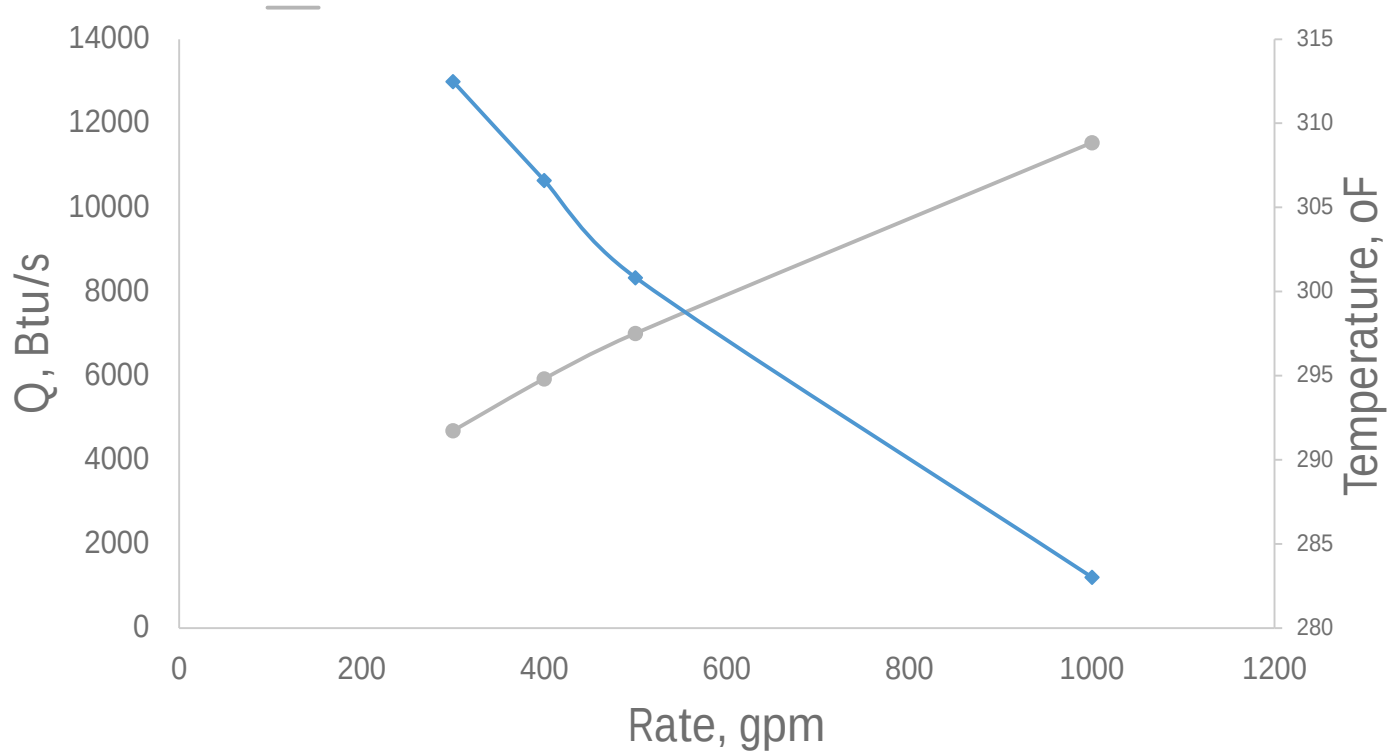

Fig: Power and Output Temperature with different rates

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