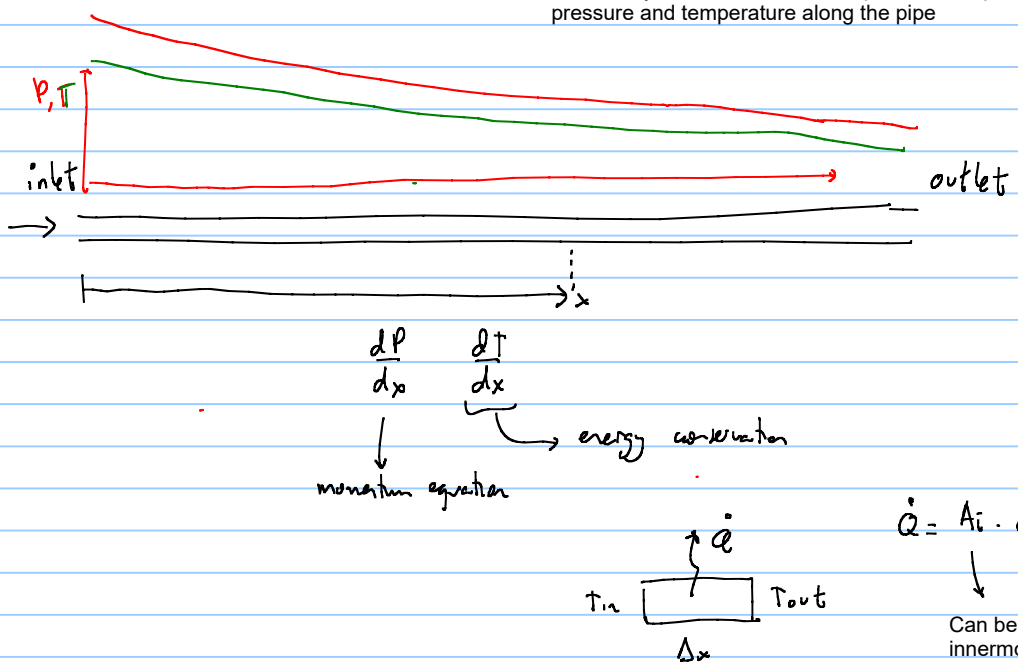
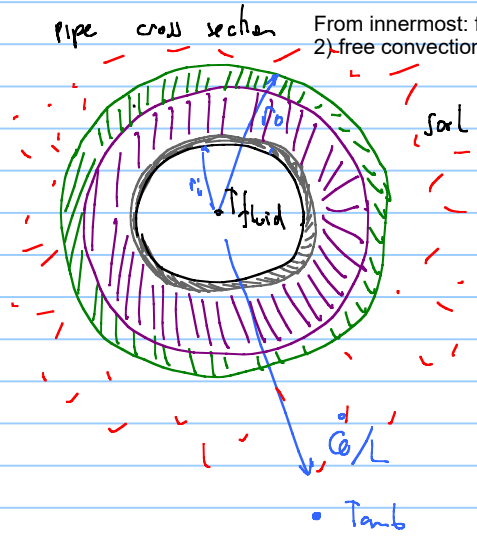
Most analysis on flow assurance problems require to compute distribution of pressure and temperature along the pipe

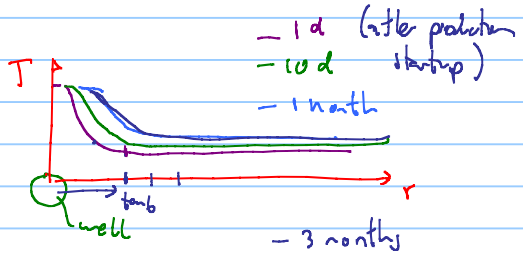


From innermost: forced convection, conduction in pipe, conduction in insulation, and 1) conduction in soil or 2) free convection with seawater



soil (buried or well) → gradual heating of soil
• seawater

Transient problem!



A clever solution proposed by Ramey

Wellbore Heat Transmission

1962

H. J. RAMEY, JR. MEMBER AIME | MOBIL OIL CO. SANTA FE SPRINGS, CALIF.

When the temperature of the formation is changing, U_o must be substituted by the transient overall heat transfer coefficient $U_f(t)$, defined by:

$$U_f(t) = \frac{U_o \cdot k_{soil}}{k_{soil} + r_{ins,o} \cdot U_o \cdot f(t)} \quad \text{EQ. D-21}$$

$$f(t) = -ln\left(\frac{r_{ins,o}}{2 \cdot \sqrt{\alpha_{soil} \cdot t}}\right) - 0{,}29 \quad \text{EQ. D-22}$$

$$\alpha_{soil} = \frac{k_{soil}}{\rho_{soil} \cdot C_{p,soil}} \quad \text{EQ. D-23}$$

Where:

k_{soil}	Thermal conductivity, soil [W/m.K]
$C_{p,soil}$	Specific heat capacity, soil [J/K.kg]
α_{soil}	Thermal diffusivity, soil [m^2/s]
t	Time [s]

It is important to make an order or magnitude analysis on the terms that make up the U and determine which one are most

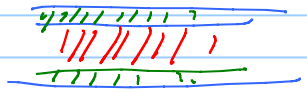
$$\frac{1}{U_i} = \frac{1}{h_i} + \frac{r_i \cdot \ln\left(\frac{r_i}{r_o}\right)}{k_p} + \frac{r_i \cdot \ln\left(\frac{r_{ins,o}}{r_o}\right)}{k_{ins}} + \frac{r_i}{r_{ins,o} \cdot h_o}$$

it might be low contribution

low contribution to "U"

significant contribution

medium contribution



CHECK APPENDIX C and D of compendium!