Closed-Loop WB Components

- Wellbore Thermal Modeling (Warming/Cooling)
- Liquid Drop Out (Build-ups)
- Liquid Surge (Start-up)
- Phase Behaviour EOS Calcs
  - Use SRK or PR w/Peneloux
- Rate Modeling
  - Residence Time
  - Rate Surging & Decay
- Coupled Effects (Rate-Thermal-Phase)

Developing Thermal/PVT Models

- Run Static Temp/Pressure Survey
- Run Flowing Temp/Pressure Survey
  - Multiple Rates
- Develop Heat Transfer Model – Account for:
  - Heat Capacity of Fluids/Tubulars/Annuli/Sinks
  - Heat X-fer via Conduction
  - Heat X-fer via Convection
  - Heat X-fer via Forced Convection
- Can Tune PVT using same data…just get a good sample first

Continuity Equation

$$\frac{\partial \rho}{\partial t} = -(\nabla \bullet \rho v)$$

- Rate of Change in Density Caused by Changes in Mass Flux

Differential Form of Bernoulli Eqn Compressible Conditions

$$\Delta \tfrac{1}{2}(v)^2 + g\Delta h + \int_{p1}^{p2} dp/\rho + Ws +$$

$$\sum_i \left(\tfrac{1}{2} v^2 \tfrac{L}{R_h} f\right)_i + \sum_i \left(\tfrac{1}{2} v^2 e_v\right)_i = 0$$

Mechanical Energy Balance (Single Phase Gas)

- For Single-Phase Gas Flow in Pipes, the MEB reduces to:

$$dp/\rho = -(g \sin \theta / g_c + 2 f_f u^2 / g_c D) \, dL$$

- Basis for CS, Gray & A-C

Bernoulli for Single Phase Oil Incompressible Conditions

$$\frac{dp}{d\rho} + \frac{vdv}{g_C} + \frac{g}{g_c}dz + \frac{2 f_f v^2 dL}{g_c D} + dW_s = 0$$

- Basis for Hagedorn-Brown & Beggs/Brill

Bernoulli Solution Process

Build Parametric Models & Well Configuration

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Assume Continuity

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Solve Bernoulli (MEB)

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Check Continuity

Note: If Continuity Doesn’t Hold, the Well is Loading–up (which is important to know)

Using a Direct Bernoulli Solution for WB

- Works for Oil, Gas or Water (Continuity)
- Gas
  - Have DP, solve for rate
  - Have Rate, solve for DP
- Oil
  - Have Rate, solve for Water cut
  - Have DP, solve for Water cut
- Much Easier to Apply Parametric Models Continuously:
  - Thermal Transients
  - Rate Transients
  - Phase Transients
  - Combined Rate, Phase & Thermal Transients