POWER LAW MODEL

Dr. Raed H. Allawi

Determine **n** and **K** from equations

- $\mathbf{n = 3.32 \log \frac{\theta_{600}}{\theta_{300}}}$
- $\mathbf{K = \frac{\theta_{300}}{511^{n_p}}}$
- Where:
- θ_{600} **= 2 PV + YP**
- θ_{300} **= PV + YP**

Pipe Flow

- $\mathbf{\acute{V}} = \frac{\mathbf{24.5 \times Q}}{\mathbf{D^2}}$

- $\mathbf{V_c} = \left(\frac{\mathbf{5.82 \times 10^4 \times K}}{\boldsymbol{\rho}}\right)^{\left(\frac{\mathbf{1}}{\mathbf{2-n}}\right)} \left(\frac{\mathbf{1.6 \times (3n+1)}}{\mathbf{D \times 4n}}\right)^{\left(\frac{\mathbf{n}}{\mathbf{2-n}}\right)}$

- If $\acute{V} > V_c$, flow is turbulent; use $\mathbf{P} = \frac{\mathbf{8.91 \times 10^{-5} \times \rho^{0.8} \times Q^{1.8} \times PV^{0.2} \times L}}{\mathbf{(D)^{4.8}}}$

- If $\acute{V} < V_c$, flow is laminar; use $\mathbf{P} = \left(\frac{\mathbf{KL}}{\mathbf{300D}}\right)\left(\frac{\mathbf{1.6\acute{V} \times (3n+1)}}{\mathbf{D \times 4n}}\right)^{\mathbf{n}}$

Annular Flow

- $\acute{V} = \frac{24.5 \times Q}{D_h^2 - OD^2}$

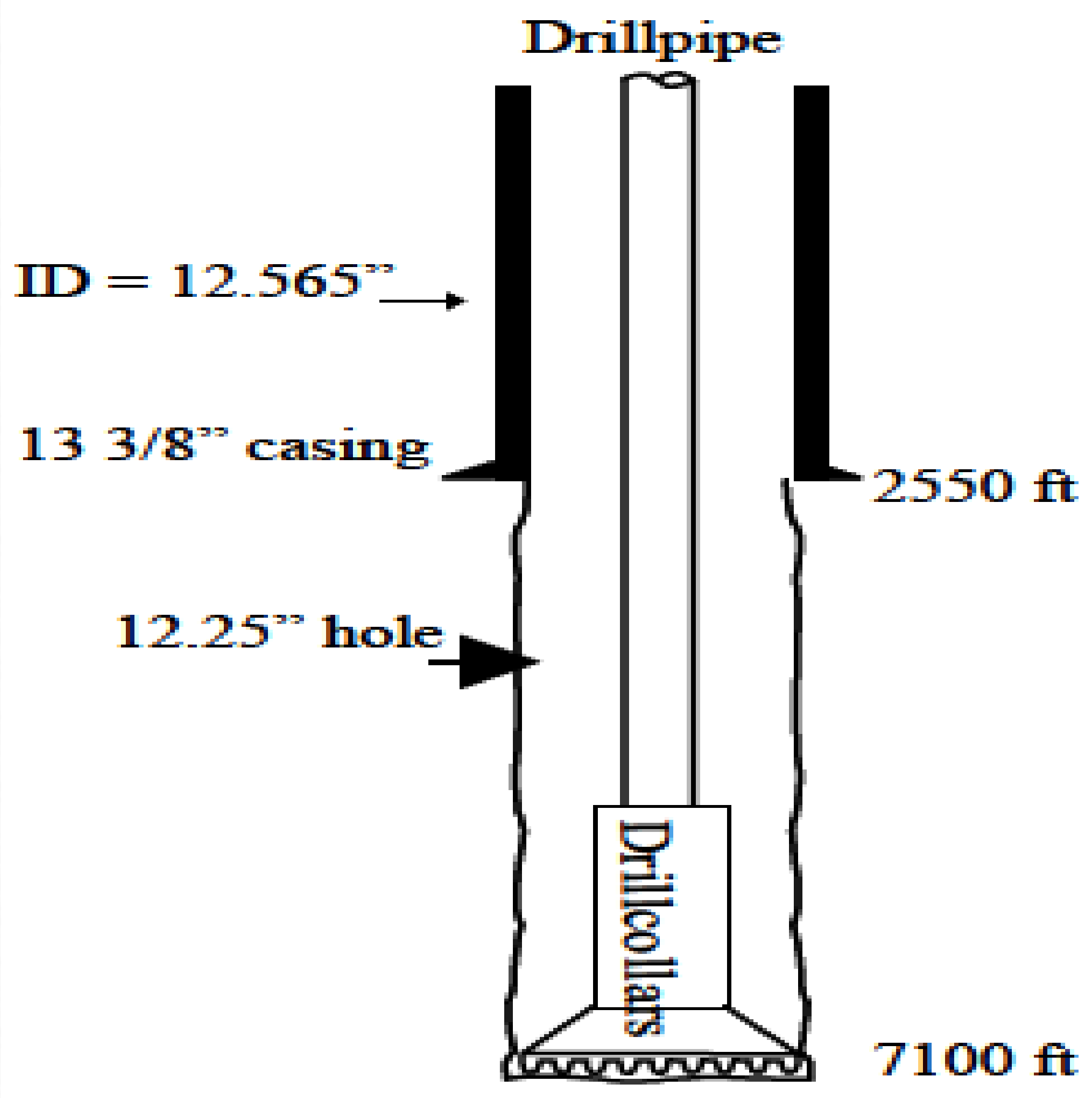
- $V_c = \left(\frac{3.878 \times 10^4 \times K}{\rho}\right)^{\left(\frac{1}{2-n}\right)} \left(\frac{2.4 \times (2n+1)}{D_e \times 3n}\right)^{\left(\frac{n}{2-n}\right)}$

- If $\acute{V} > V_c$, flow is turbulent; use $P = \frac{8.91 \times 10^{-5} \times \rho^{0.8} \times Q^{1.8} \times PV^{0.2} \times L}{(D_h - OD)^3 (D_h + OD)^{1.8}}$

- If $\acute{V} < V_c$, flow is laminar; use $P = \left(\frac{K * L}{300 D_e}\right)\left(\frac{2.4\acute{V} \times (3n+1)}{D_e \times 3n}\right)^n$

Ex.17: Using the Bingham plastic and power-law models, determine the various pressure drops, nozzle velocity and nozzle sizes for a section of **12.25** in (**311**mm) hole. Two pumps are used to provide **700** gpm (**2650** l/min). **The Data:**

- Plastic viscosity = **12** cp, Yield point = **12** lb/100 ft^2 Mud weight = **8.8** lb/gal
- Drillpipe (ID = **4.276** in, OD = **5** in, length = **6480** ft)
- Drill collars (ID = **2.875** in, OD = **8** in, length = **620** ft (**189** m))
- Last casing was **13.375** in with an ID of **12.565** in. **13.375** in casing was set at **2550** ft.
- The two pumps are to be operated at a maximum standpipe pressure of **2200** psi.
- Assume a surface equipment type of **4**.


Drillpipe
ID = 12.565"
13 3/8" casing
2550 ft
12.25" hole
Drillcollars
7100 ft

Bingham Plastic Model

- **Solution:**

Surface losses

- $P_1 = Ex\ \rho^{0.8} \times Q^{1.8} \times PV^{0.2} = 52$ psi
- $P_1 = 4.2 \times 10^{-5} \times 8.8^{0.8} \times 700^{1.8} \times 12^{0.2} =$ **52 psi**

Pipe losses

Pressure losses inside drillpipe

- $\acute{V} = \frac{24.5 \times Q}{D^2} = \frac{24.5 \times 700}{(4.276)^2} = 937.97 \text{ ft/min}$

- $V_C = \frac{97\ PV + 97\sqrt{PV^2 + 8.2\rho D^2 Y_P}}{\rho D} = \frac{97 * 12 + 97\sqrt{12^2 + 8.2 * 8.8 * 4.276^2 * 12}}{8.8 * 4.276} = 356.76 \text{ ft /min}$

- Since $\acute{V} > V_c$, flow is turbulent and pressure drop inside drill pipe is calculated from:

- $P_2 = \frac{8.91 \times 10^{-5} \rho^{0.8} Q^{1.8} PV^{0.2} L}{D^{4.8}} = \frac{8.91 \times 10^{-5} \times 8.8^{0.8} \times 700^{1.8} \times 12^{0.2} \times 6480}{4.276^{4.8}} = \mathbf{668.45\ psi}$

Pressure losses inside drill collars

- $\acute{V} = \frac{24.5 \times Q}{D^2} = \frac{24.5 \times 700}{(2.875)^2} = 2074.85 \text{ ft/min}$

- $V_C = \frac{97\ PV + 97\sqrt{PV^2 + 8.2\rho D^2 Y_P}}{\rho D} = \frac{97*12+97\sqrt{12^2+8.2*8.8*2.875^2*12}}{8.8*3} = 373.61 \text{ ft /min}$

- Since $\acute{V} > V_c$, flow is turbulent and pressure drop inside drill collar is calculated from:

- $P_3 = \frac{8.91 \times 10^{-5} \rho^{0.8} Q^{1.8} PV^{0.2} L}{D^{4.8}} = \frac{8.91 \times 10^{-5} \times 8.8^{0.8} \times 700^{1.8} \times 12^{0.2} \times 620}{2.875^{4.8}} = \mathbf{429.93\ psi}$

Pressure losses around drillcollar: Open hole section

- $\acute{V} = \frac{24.5 \times Q}{Dh^2 - OD^2} = \frac{24.5 \times 350}{12.25^2 - 8^2} = 199.27 \text{ ft /min}$

- $V_C = \frac{97\ PV + 97\sqrt{PV^2 + 6.2\rho D_e^2 Y_P}}{\rho D} = \frac{97*12 + 97\sqrt{12^2 + 6.2*8.8*(12.25-8)^2*12}}{8.8*(12.25-8)} = 314.87 \text{ ft /min}$

- Since $\acute{V} < V_c$, flow is laminar and the pressure loss around the drillcollar is determined

from:

- $P_4 = \frac{L\ PV\ V'}{60000\ D_e^2} + \frac{L\ Y_p}{225\ D_e} = \frac{620 \times 12 \times 199.27}{60000\ (12.25-8)^2} + \frac{620 \times 12}{225\ (12.25-8)} = \mathbf{9.14\ psi}$

Pressure losses around drillpipe: Open hole section

- $\acute{V} = \frac{24.5 \times Q}{Dh^2 - OD^2} = \frac{24.5 \times 350}{12.25^2 - 5^2} = 137.13 \text{ ft /min}$

- $V_C = \frac{97\ PV + 97\sqrt{PV^2 + 6.2 \rho D_e^2 Y_P}}{\rho D} = \frac{97*12 + 97\sqrt{12^2 + 6.2*8.8*(12.25-5)^2*12}}{8.8*(12.656-5)} = 300.87 \text{ ft /min}$

- Since Ý<Vc, flow is laminar and the pressure loss around the drillpipe is determined from:

- $P_5 = \frac{L\ PV\ V'}{60000\ D_e^2} + \frac{L\ Y_p}{225\ D_e} = \frac{3930 \times 12 \times 137.13}{60000\ (12.25-5)^2} + \frac{3930 \times 12}{225\ (12.25-5)} = \mathbf{30.96\ psi}$

Pressure losses around drill pipe: Cased hole section

- $\acute{V} = \frac{24.5 \times Q}{Dh^2 - OD^2} = \frac{24.5 \times 700}{12.565^2 - 5^2} = 129 \text{ ft /min}$

- $V_C = \frac{97\ PV + 97\sqrt{PV^2 + 6.2\rho D_e^2 Y_P}}{\rho D} = \frac{97 * 12 + 97\sqrt{12^2 + 6.2 * 8.8 * (12.565 - 5)^2 * 12}}{8.8 * (12.565 - 5)} = 300 \text{ ft /min}$

- Since V́<Vc, flow is laminar and the pressure loss around the drillpipe is determined from:

- $P_6 = \frac{L\ PV\ V'}{60000\ D_e^2} + \frac{L\ Y_p}{225\ D_e} = \frac{2550 \times 12 \times 129}{60000\ (12.565 - 5)^2} + \frac{2550 \times 12}{225\ (12.565 - 5)} = \mathbf{19.12\ psi}$

Pressure drops across bit

- Total pressure loss in circulating system, except bit.

- $\Delta P_{Total} = P_1 + P_2 + P_3 + P_4 + P_5 + P_6$
- $= 52 + 668.45 + 429.93 + 19.12 + 30.96 + 9.14 =$ **1209.6 psi**
- Therefore, pressure drop available for bit (P_{bit})
- $\Delta P_{bit} = 2200 – 1209.6 =$ **990.4 psi**

Determine nozzle velocity (ft/s)

- $V_n = 33.36\sqrt{\frac{P_{bit}}{\rho}}$

- $V_n = 33.36\sqrt{\frac{990.4}{8.8}} = 353.9 \text{ ft/s}$

Determine total area of nozzles (in²)

- $A_n = \frac{0.32*Q}{V_n} = \frac{0.32*700}{353.9} = 0.632 in^2$

- Nozzle size (in multiples of (1/32)

- $d_n = 32\sqrt{\frac{4*A_n}{3*\pi}} = 32*\sqrt{\frac{4*0.632}{3*\pi}} = 16.57''$

- Hence, select two nozzles of size 17 and one of size 16.

B.H.C.P.

- B.H.C.P. = $0.052\rho D + \Delta P_{ap} + \Delta P_{ac}$
- = 0.052*8.8*7100 + 50 + 9.14 = **3308 psi**
- $\mathrm{E.C.D.} = \mathrm{IMW} + \frac{\Delta_{ap} + \Delta_{ac}}{0.052 \times D}$
- $\mathrm{E.C.D.} = 8.8 + \frac{50 + 9.14}{0.052 \times 7100} = \mathbf{8.96\ lb/gal}$

CONTACT US

raed.Allawi@alayen.edu.iq