Beggs and Brill method

The Beggs and Brill method works for horizontal or vertical flow and everything in between. It also takes into account the different horizontal flow regimes. This method uses the general mechanical energy balance and the average in-situ density to calculate the pressure gradient. The following parameters are used in the calculations.

$$N_{FR} = \frac{u_m^2}{gD} \qquad (2\text{-}38)$$

$$\lambda_l = \frac{u_l}{u_m}$$

$$L_1 = 316\lambda_l^{0.302} \qquad L_2 = .0009252\lambda_l^{-2.4684} \qquad (2\text{-}39,\ 40)$$

$$L_3 = .10\lambda_l^{-1.4516} \qquad L_4 = .5\lambda_l^{-6.738} \qquad (2\text{-}41,\ 42)$$

Determining flow regimes

Segregated if

$\lambda_l < .01$ and $N_{FR} < L_1$ or $\lambda_l >= .01$ and $N_{FR} < L_2$

Transition if

$\lambda_l >= .01$ and $L_2 < N_{FR} <= L_3$

Intermittent if

$.01 <= \lambda_l < .4$ and $L_3 < N_{FR} <= L_1$ or $\lambda_l >= .4$ and $L_3 < N_{FR} <= L_4$

Distributed if

$\lambda_l < .4$ and $N_{FR} >= L_1$ or $\lambda_l >= .4$ and $N_{FR} > L_4$

For segregated, intermittent and distributed flow regimes use the following:

$$y_l = y_{l0}\varphi \qquad y_{l0} = \frac{a\lambda_l^b}{N_{FR}^c} \qquad (2\text{-}43,\ 44)$$

with the constraint of that $y_{l0} >= \lambda_l$.

$$\psi = 1 + C\left[\sin(1.8\theta) - .333\sin^3(1.8\theta)\right] \qquad C = (1-\lambda_l)\ln\left(d\lambda_l^e N_{vl}^f N_{FR}^g\right) \qquad (2\text{-}45,46)$$

Where a, b, c, d, e, f and g depend on flow regimes and are given in the following table

**Beggs and Brill holdup constants**

| Flow regime | $a$ | $b$ | $c$ | |
|---|---|---|---|---|
| Segregated | 0.98 | 0.4846 | 0.0868 | |
| Intermittent | 0.845 | 0.5351 | 0.0173 | |
| Distributed | 1.065 | 0.5824 | 0.0609 | |
| | $d$ | $e$ | $f$ | $g$ |
| Segregated uphill | 0.011 | −3.768 | 3.539 | −1.614 |
| Intermittent uphill | 2.96 | 0.305 | −0.4473 | 0.0978 |
| Distributed uphill | No correction, $C = 0$, $\psi = 1$ | | | |
| All regimes downhill | 4.70 | −0.3692 | 0.1244 | −0.5056 |

For transition flow, the liquid holdup is calculated using both the segregated & intermittent equations and interpolating using the following:

$$y_l = Ay_l(Segregated) + By_l(Intermittent) \qquad (2\text{-}47)$$

$$A = \frac{L_3 - N_{FR}}{L_3 - L_2} \qquad B = 1 - A \qquad (2\text{-}48,49)$$

$$\bar{\rho} = y_l\rho_l + y_g\rho_g \qquad \left(\frac{dp}{dl}\right)_{PE} = \frac{g}{g_c}\frac{\bar{\rho}\sin\theta}{144} \qquad (2\text{-}50,51)$$

The frictional pressure gradient is calculated using:

$$\left(\frac{dp}{dl}\right)_{F} = \frac{2 f_{tp}\rho_m u_m^2}{g_c D} \qquad (2\text{-}52)$$

$$\rho_m = \rho_l\lambda_l + \rho_g\lambda_g \qquad f_{tp} = f_n\frac{f_{tp}}{f_n} \qquad (2\text{-}53,54)$$

The no slip friction factor $f_n$ is based on smooth pipe ($\varepsilon/D = 0$) and the Reynolds number,

$$N_{\mathrm{Re}m} = \frac{\rho_m u_m D 1488}{\mu_m} \quad \text{where} \quad \mu_m = \mu_l \lambda_l + \mu_g \lambda_g \qquad (2\text{-}55,56)$$

$f_{tp}$ the two phase friction factor is

$$f_{tp} = f_n e^S \qquad (2\text{-}57)$$

where

$$S = \frac{\ln(x)}{\left(-0.0523 + 3.182\ln(x) - 0.8725[\ln(x)]^2 + 0.01853[\ln(x)]^4\right)} \qquad (2\text{-}58)$$

and

$$x = \frac{\lambda_l}{y_l^2} \qquad (2\text{-}59)$$

Since S is unbounded in the interval $1 < x < 1.2$, for this interval

$$S = \ln(2.2x - 1.2) \qquad (2\text{-}60)$$

Using Beggs & Brill (Same data is Duklar example)

First find the flow regime, calculate $N_{FR}$, $\lambda_l$, $L_1$, $L_2$, $L_3$, and $L_4$.

$N_{FR}$ = 18.4, $\lambda_l$ = .35, $L_1$=230, $L_2$=.0124, $L_3$= .456, $L_4$= 590.

So $.01 < \lambda_l < .4$ and $L_3 < N_{FR} < L_1$ so flow is intermittent.

Using the table to get a, b and c:

$$y_{l0} = \frac{a\lambda_l^b}{N_{FR}^c} = \frac{.845 * .35^{0.5351}}{29.6^{0.0173}} = 0.454$$

Find C and $\psi$, d, e, f and g from table:

$$C = (1-\lambda_l)\ln\left(d\lambda_l^e N_{vl}^f N_{FR}^g\right) = (1-.35)\ln\left(2.96 * .35^{0.305} * 10.28^{-0.4473} * 29.6^{0.0978}\right) = 0.0351$$

$$\psi = 1 + C\left[\sin(1.8\theta) - .333\sin^3(1.8\theta)\right) = 1 + .0351\left[\sin(1.8*90) - .333\sin^3(1.8*90)\right]\right] = 1.01$$

Find $y_l$

$$y_l = y_{l0}\psi = .454 * 1.01 = .459$$

The in-situ average density is

$$\bar{\rho} = y_l\rho_l + y_g\rho_g = .459 * 49.9 + (1-.459) * 2.6 = 24.29 lb/ft^3$$

Potential gradient is

$$\left(\frac{dp}{dl}\right)_{PE} = \frac{g}{g_c}\frac{\bar{\rho}\sin\theta}{144} = \frac{24.29 * 1}{144} = .169 psi/ft$$

For friction gradient

First find the mixture density and viscosity

$$\rho_m = \rho_l\lambda_l + \rho_g\lambda_g = 49.9 * .35 + 2.6 * .65 = 19.1 lb/ft^3$$
$$\mu_m = \mu_l\lambda_l + \mu_g\lambda_g = 2 * .35 + .0131 * .65 = .709 cp$$

The Reynolds Number

$$N_{\text{Re}m} = \frac{\rho_m u_m D 1488}{\mu_m} = \frac{19.1 * 13.39 * .203 * 1488}{.709} = 109184$$

From Moody plot $f_n$ is .0045, solve for S

$$x = \frac{\lambda_l}{y_l^2} = \frac{.35}{.459} = 1.66$$

$$S = \frac{\ln(x)}{\left(-0.0523 + 3.182\ln(x) - 0.8725[\ln(x)]^2 + 0.01853[\ln(x)]^4\right)}$$

$$S = \frac{\ln(1.66)}{\left(-0.0523 + 3.182\ln(1.66) - 0.8725[\ln(1.66)]^2 + 0.01853[\ln(1.66)]^4\right)} = .379$$

Solve for $f_{tp}$

$$f_{tp} = f_n e^S = .0045 e^{.379} = .0066$$

Find the friction gradient

$$\left(\frac{dp}{dl}\right)_F = \frac{2 f_{tp} \rho_m u_m^2}{g_c D} = \frac{2 * .0066 * 19.1 * 10.94^2}{32.17 * 203} = 4.62 lb/ft^3 = .032 psi/ft$$

1)Using the Beggs and Brill method find the length of pipe between the points at 1000psi and 500 psi with the following data. Both vertical and horizontal cases.

| | | | |
|---|---|---|---|
| d = 1.995” | $\gamma_g$ = .65 | oil 22$^o$ API | $q_o$ = 400 stb/day |
| $q_w$ = 600 bpd | $\mu_g$ = .013 cp | $\sigma_o$ = 30 dynes/cm | $\sigma_w$ = 70 dynes/cm |
| GLR = 500 scf/stb | | | |

@ average conditions

| | | | |
|---|---|---|---|
| $\beta_o$ = 1.063 | $R_s$ = 92 scf/stb | $\mu_o$ = 17 cp | $\mu_w$ = .63 |
| z = .91 | | | |

Table 10-1

**Equivalent Lengths of Valves and Fittings[a]**

| | | Description of Fitting | | Equivalent Length in Pipe Diameters |
|---|---|---|---|---|
| Globe valves | Stem perpendicular to run | With no obstruction in flat, bevel, or plug type seat | Fully open | 340 |
| | | With wing or pin guided disk | Fully open | 450 |
| | Y-pattern | (No obstruction in flat, bevel, or plug type seat) | | |
| | | —With stem 60° from run of pipe line | Fully open | 175 |
| | | —With step 45° from run of pipe line | Fully open | 145 |
| Angle valves | | With no obstruction in flat, bevel, or plug type seat | Fully open | 145 |
| | | With wing or pin-guided disk | Fully open | 200 |
| Gate valves | Wedge, disk | | Fully open | 13 |
| | Double disk or plug disk | | Three-quarters open | 35 |
| | | | One-half open | 160 |
| | | | One-quarter open | 900 |
| | Pulp stock | | Fully open | 17 |
| | | | Three-quarters open | 50 |
| | | | One-half open | 260 |
| | | | One-quarter open | 1200 |
| Conduit pipe line gate, ball, and plug valves | | | Fully open | 3 |
| Check valves | Conventional swing | | Fully open | 135 |
| | Clearway swing | | Fully open | 50 |
| | Globe life or stop; stem perpendicular to run or Y-pattern | | Fully open | Same as globe |
| | Angle lift or stop | | | Fully open |
| | Same as angle | | | |
| | In-line ball | | Fully open | 150 |

## Equivalent Lengths of Valves and Fittings[a]

| | | Description of Fitting | | Equivalent Length in Pipe Diameters |
|---|---|---|---|---|
| Foot valves with strainer | | With poppet lift-type disk | Fully open | 420 |
| | | With leather-hinged disk | Fully open | 75 |
| Butterfly valves (8 in. and larger) | | | Fully open | 40 |
| Cocks | Straight-through | Rectangular plug port area equal to 100% of pipe area | Fully open | 18 |
| | Three-way | Rectangular plug port area equal to 80% of pipe area (fully open) | Flow straight through | 44 |
| | | | Flow through branch | 140 |
| Fittings | 90° standard elbow | | | 30 |
| | 45° standard elbow | | | 16 |
| | 90° long radius elbow | | | 20 |
| | 90° street elbow | | | 50 |
| | 45° street elbow | | | 26 |
| | Square corner elbow | | | 57 |
| | Standard tee | With flow through run | | 20 |
| | | With flow through branch | | 60 |
| | Close-pattern return bend | | | 50 |

[a]From Crane (1957).

Pipe Fittings in Horizontal flow

To find the pressure drop through pipe fitting such as elbows, tees and valves an equivalent length is add to the flow line.  This will account for the additional turbulence and secondary flows which cause the additional pressure drop.

These equivalent lengths have been determined experimentally for the most of the fittings.  These are found in the following tables.  They are given in pipe diameters, which are in feet.

So to find the equivalent length for a $45^o$ elbow in 2 inch pipe, find the equivalent length for the elbow in the table, 16, and multiply it by .166 feet, which gives 2.66 feet.  This is added to the length of the flow line, the pressure drop for the system is then calculated using one of the methods for horizontal flow.