$ft_{Head} := 0.433psi$

Guess Values and Definition of Key Variables

$Q_T := 500gpm$		Total Flow (T)
$Q_R := 3000gpm$		Recyle Flow (R)
$Q_{BW} := 1200gpm$		Backwash Flow (BW)
$L_{BW} := 275ft$	$L_R := 70ft$	Length of BW and R lines
$D_{BW} := 30in$	$D_R := 12in$	Diameter of BW and R lines
$V_{BW} := 4\frac{ft}{s}$	$V_R := 5\frac{ft}{s}$	Velocity of BW and R lines
$\Delta P_{BW} := 1psi$		Additional pressure added by BW valve
$\Delta P_{Valve} := 10psi$		Additional pressure added by R valve
$h_R := 10psi$		
$\Delta K := 15$		Delta K of Recycle Valve
$\Delta H := 1psi$		Difference between head of pump curve and the calculated solution
$P_{OpenR} := 11\%$		Position of R Valve
$CV_R := 1000$		Calculated CV of R Valve
$Open_{CVR} := 10000$		CV of BW valve - Fully Open
$CV_{BW} := 2332$		Calculated CV of BW valve
$Open_{CVBW} := 1000$		CV of BW valve - Fully Open
$P_{OpenBW} := 11\%$		Percent Open of BW valve
$\rho := 1000\frac{kg}{m^3}$		Density of Water

$f_R := 0.035$ — Friction factor from Moody Diagram

$f_{BW} := 0.035$ — Friction factor from Moody Diagram

$k_R := 10$ — Total of k values in R system (fittings, bends, etc.)

$k_{BW} := 5.66$ — Total of k values in BW system (fittings, bends, etc.)

$h_{Pump} := 50ft_{Head}$ — Head of pump

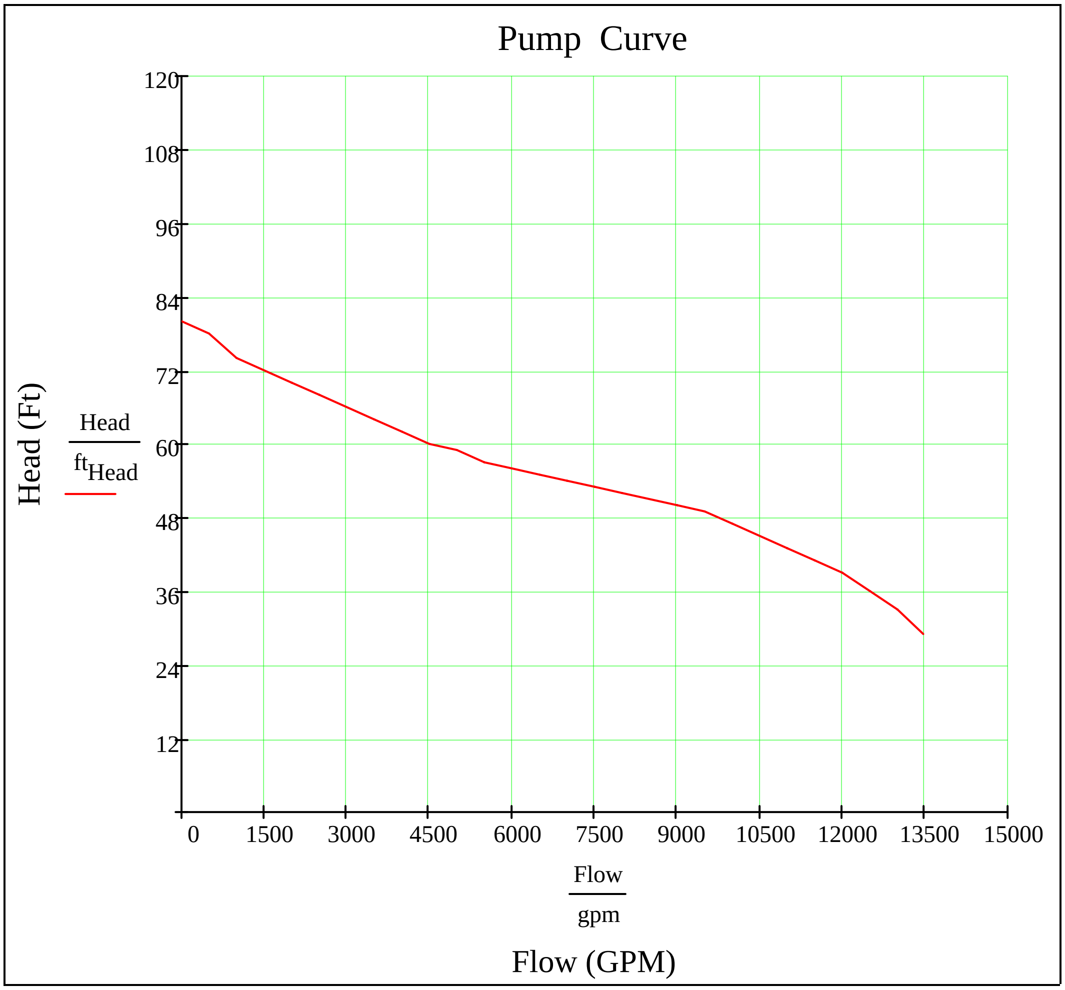
$h_{System} := 50ft_{Head}$ — Head of BW System

$h_{Common} := 5ft_{Head}$ — Headloss through Common line

$\begin{pmatrix} Column1 \\ Column2 \end{pmatrix} :=$ [redacted]

$Flow := Column1^{\langle 0 \rangle} \cdot gpm$

$Head := Column2^{\langle 0 \rangle} \cdot ft_{Head}$



data :=

	0	1
0	500	78
1	1000	74
2	1500	72
3	2000	70
4	2500	68
5	3000	66
6	3500	64
7	4000	62
8	4500	60
9	5000	...

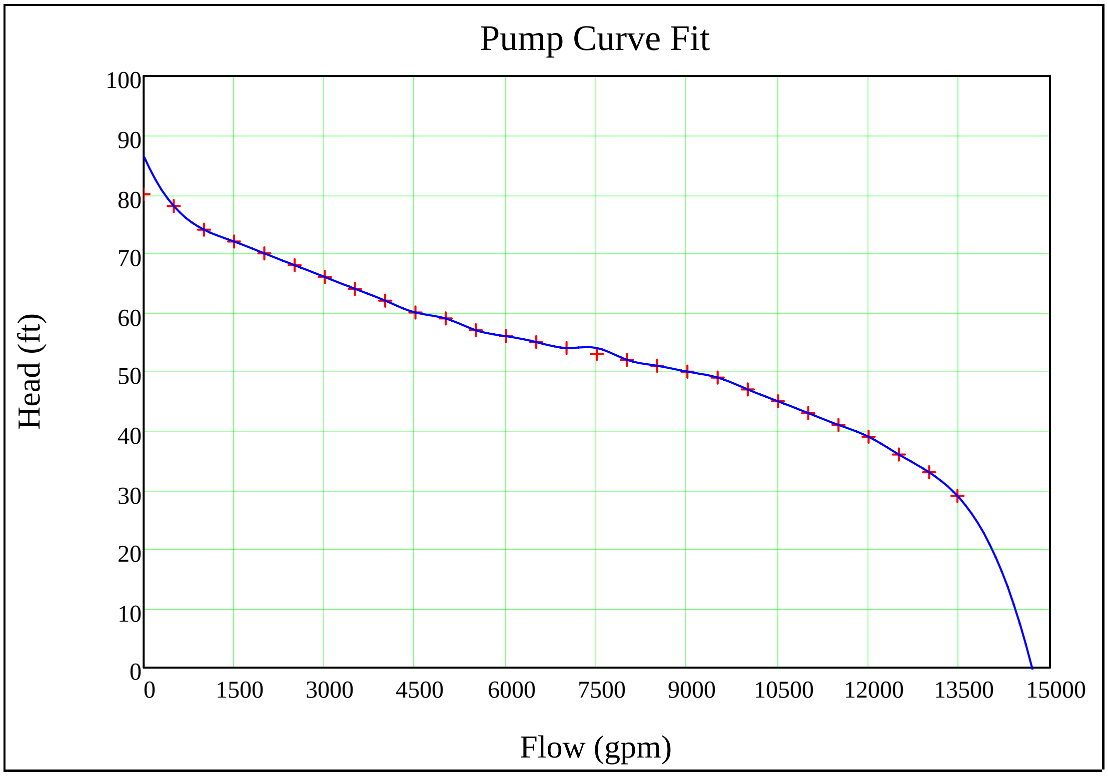
data := csort(data, 0) $X := data^{\langle 0 \rangle} \cdot gpm$ $Y := data^{\langle 1 \rangle} \cdot ft_{Head}$

Spline coefficients:

$S := \text{cspline}(X, Y)$ $Q := 0\text{gpm}, 100\text{gpm} .. 15000\text{gpm}$

Fitting function:

$\text{Pumpfit}(x) := \text{interp}(S, X, Y, x)$



$L_C := 763\text{ft}$

$k_C := 13.68$

$f_C := .035$

$V_C := 5\frac{\text{ft}}{\text{s}}$

$D_C := 34.5\text{in}$

System :=

	0	1	2
0	3	0	0
1	4	0	0
2	6	0	0
3	8	0	0
4	10	0	0
5	12	0	0
6	14	0	0
7	16	0	0
8	20	0	0
9	24	14	1.46
10	30	145	2.89
11	36	19	2.26
12	42	570	7.595
13	48	0	0
14	54	0	0
15	60	0	0
16	66	0	0
17	72	0	0

$D := System^{\langle 0 \rangle}\,in$

$HWL_{Destination} := 6.5ft$

$LWL_{Origin} := 0ft$

$L := System^{\langle 1 \rangle} \cdot ft$

$K := System^{\langle 2 \rangle}$

$C_{Pipe} := 120$

$h_{FrictionPipe} := 1ft$

$h_{Static} := 1ft$

$h_{FrictionFittings} := 1ft$

System :=

	0	1	2
0	0	6.5	
1	700	6.5	
2	1400	6.6	

3	2100	6.7	
4	2400	6.7	
5	2600	6.8	
6	2800	6.8	
7	3500	7	
8	4200	7.2	
9	4510	7.3	
10	5600	7.8	
11	6300	8.1	
12	7000	8.5	
13	7700	8.9	
14	8400	9.4	
15	9100	9.9	
16	9800	10.4	
17	10210	...	

$data1 := csort(System, 0)$ $\quad A := System^{\langle 0 \rangle} \cdot gpm$ $\quad B := System^{\langle 1 \rangle} ft_{Head}$

Spline coefficients:

$R := cspline(A, B)$

Fitting function:

$Commonfit(x) := interp(R, A, B, x)$

Given

BW System Parameters

$\rho = 1000 \frac{kg}{m^3}$ Density of Water

$Q_T = Q_{BW} + Q_R$ Conservation of Flow

$Q_R > 0gpm$

$Q_T > 0gpm$

$Q_{BW} > 0gpm$

Logical contstrainst for QT. Manufacturer's minimum pump flow is 3,500 gpm and above 5,000 gpm we do not need the BW control valve.

$D_{BW} = 24in$ Diameter of BW line

$L_{BW} = 220ft$ Length of BW line

$k_{BW} = 5.66$ Sum of BW line k-values

$f_{BW} = 0.035$ Friction Factor from Moody Diagram

$V_{BW} = \frac{4Q_{BW}}{\pi D_{BW}^2}$ Velocity of flow through BW line

Headloss through BW system = Piping loss + Fitting Loss+ Static Loss

$$h_{System} = \left[1.1\left(\frac{f_{BW} \cdot L_{BW} \cdot V_{BW}^2}{2 \cdot D_{BW} \cdot g} + \frac{k_{BW} \cdot V_{BW}^2}{2g}\right)\rho \cdot g + 20ft_{Head} + \left[0.0006\left(\frac{Q_{BW}}{gpm}\right) + 0.8315\right]ft_{Head}\right]$$

Estimation of Pump Curve - Based on Curve fit above

$h_{Pump} = Pumpfit(Q_T)$

Estimation of headloss through common line - Based on MS Excel 2nd order approximation

$h_{Common} = Commonfit(Q_T)$

$k_C = 13.68$ $D_C = 34.5in$

$L_C = 763ft$ $f_C = .035$

$V_C = \frac{4Q_T}{\pi D_C^2}$

Additional head imparted by BW valve

$$\Delta P_{BW} = \left[\frac{\left(\frac{Q_{BW}}{gpm}\right)^2}{CV_{BW}^{\,2}}\right] psi$$

$\Delta P_{BW} > 0psi$ Logical qualifier for ΔPBW

CV of BW valve - Fully open - based on Henry Pratt Ball Valve CV

$Open_{CVBW} = 22000$ 20" BW **Butterfly - valve**

Percent Open of BW Valve

$$P_{OpenBW} = \frac{CV_{BW}}{Open_{CVBW}}$$

Design guides recommend that a valve operate between 10% and 80% open

Recycle System Parameters

$f_R = 0.035$ Friction factor R line - Moody Diagram

$L_R = 70ft$ Length of R line after common

$D_R = 14in$ Diameter of R line

$k_R = 4.41$ Sum of k-values - R line

$$V_R = \frac{4Q_R}{\pi D_R^{\,2}}$$ Velocity of flow through R line

Headloss through Recylce line = Fitting Loss + Pipe Losses

$$h_R = \left[\frac{(\Delta K + k_R)\cdot V_R^{\,2}}{2g}\right]\cdot\rho\cdot g + \frac{f_R\cdot L_R\cdot V_R^{\,2}}{2\cdot D_R\cdot g}\cdot\rho\cdot g + 0.63ft_{Head}$$

Headloss is equal in BW and R systems

$$h_R = \Delta P_{BW} + h_{System}$$

$h_R > 0psi$ Logical qualifier for hR

Please note that:

(1) It is assumed that there is no static component to this term.
(2) The additional ΔK added by the backwash control valve is segregated from the K of the existing fittings (to be used later to calculate the valve pressure drop, which is = (ΔK^2)/2g.

$$\Delta P_{Valve} = \rho\cdot g\cdot\frac{\Delta K\cdot V_R^{\,2}}{2g}$$ Headloss added by BW control valve

$\Delta K > 0$ Logical qualifier for ΔK

$$CV_R = \frac{\frac{Q_R}{gpm}}{\sqrt{\frac{\Delta P_{Valve}}{psi}}}$$ Calculated CV of BW control valve

$\Delta P_{Valve} < 150psi$ Logical qualifier for ΔPvalve

$P_{OpenR} = \frac{CV_R}{Open_{CVR}}$

$Open_{CVR} = 12000$ Fully open ball valve CV - Henry Pratt - 8" **Ball valve**

Design guides recommend operating a valve between 10-80% open

At the precise solution, ΔH=0

$\Delta H = (h_{Common} + h_{System} + \Delta P_{BW} + h_R) - h_{Pump}$ BW flow rate desired

$\Delta H \geq -1ft_{Head}$ $\Delta H \leq 1ft_{Head}$ Desired tolerance of ΔH solution

$Q_{BW} = 1750gpm$ $CV_{BW} = 18000$

Resu

$$\begin{pmatrix} h_{SystemSOL} \\ h_{PumpSOL} \\ h_{CommonSOL} \\ Q_{RSOL} \\ Q_{TSOL} \\ Q_{BWSOL} \\ \Delta P_{BWSOL} \\ h_{RSOL} \\ \Delta K_{SOL} \\ \rho_{SOL} \\ f_{RSOL} \\ L_{RSOL} \\ D_{RSOL} \\ k_{RSOL} \\ \Delta H_{SOL} \\ V_{RSOL} \end{pmatrix}$$

$$\begin{pmatrix} V_{BWSOL} \\ L_{BWSOL} \\ D_{BWSOL} \\ \Delta P_{ValveSOL} \\ CV_{RSOL} \\ CV_{BWSOL} \\ P_{OpenRSOL} \\ Open_{CVSOL} \\ k_{BWSOL} \\ P_{OpenBWSOL} \\ Open_{CVBWSOL} \\ k_{CSOL} \\ L_{CSOL} \\ V_{CSOL} \\ D_{CSOL} \\ h_{StaticSOL} \\ h_{FrictionPipeSOL} \\ h_{FrictionFittingsSOL} \\ C_{PipeSOL} \end{pmatrix} := \text{Find}\left(h_{System}, h_{Pump}, h_{Common}, Q_R, Q_T, Q_{BW}, \Delta P_{BW}, h_R, \Delta K, \rho, f_R, L_I\right.$$

Results

$P_{OpenRSOL} = 27 \cdot \%$

Flow Rates

$Q_{TSOL} = 7447.4 \cdot \frac{gal}{min}$ $\quad Q_{BWSOL} = 1750 \cdot \frac{gal}{min}$ $\quad Q_{RSOL} = 5697 \cdot \frac{gal}{min}$

Velocities

$V_{BWSOL} = 1.241 \cdot \frac{ft}{s}$ $\quad V_{RSOL} = 11.874 \cdot \frac{ft}{s}$

Headloss

$h_{PumpSOL} = 54 \cdot ft_{Head}$

$h_{SystemSOL} = 22.13 \cdot ft_{Head}$

$h_{RSOL} = 22.15 \cdot ft_{Head}$

$h_{CommonSOL} = 8.77 \cdot ft_{Head}$

$\boxed{\Delta H_{SOL} = -1 \cdot ft_{Head}}$

CVs

$CV_{BWSOL} = 18000$ $CV_{RSOL} = 3217$

$\Delta P_{ValveSOL} = 7.242 \cdot ft_{Head}$ $\Delta P_{BWSOL} = 0.022 \cdot ft_{Head}$

$\Delta K_{SOL} = 3$

Percent Open

$P_{OpenRSOL} = 26.811 \cdot \%$ $P_{OpenBWSOL} = 81.81824 \cdot \%$

$_R, D_R, k_R, \Delta H, V_R, V_{BW}, L_{BW}, D_{BW}, \Delta P_{Valve}, CV_R, CV_{BW}, P_{OpenR}, Open_{CVR}, k_{BW}, P_{OpenBW}, Open_{C}$

$CVBW, k_C, L_C, V_C, D_C, h_{FrictionPipe}, h_{FrictionFittings}, h_{Static}, C_{Pipe})$