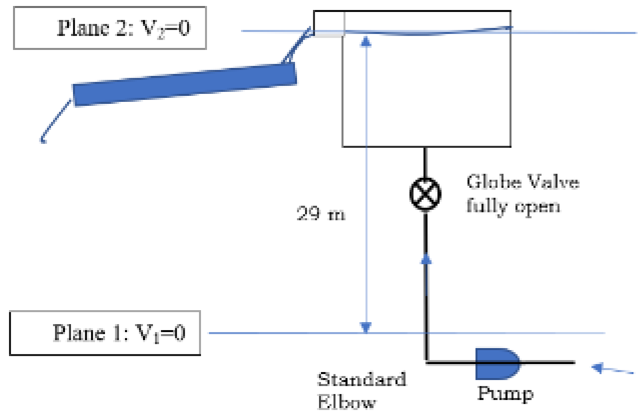
Pumping Problem

Find the size of pipe that minimizes the total annual capital plus operating cost assuming a 10 year service life and i=12%.   Assume the pipe's installed cost per foot is $65 + $100*(Dia/in)^1.5 with a salvage value of $10*(Dia/in) per ft. Schedule 40 steel pipe is available in nominal integer inch diameter increments. The pump runs 50% of the time.   Energy costs are $60/MW*hr



$GLD := 7 \qquad ELD := 15 \qquad \Delta z := 29 \cdot m \qquad f := 0.004 \qquad C := \frac{0.00000006}{W \cdot hr}$ k$/W*hr

$W := \pi \cdot 1 \cdot m^2 \cdot 10 \cdot m \cdot 1000 \cdot \frac{kg}{m^3} \cdot \frac{1}{1200 \cdot s}$

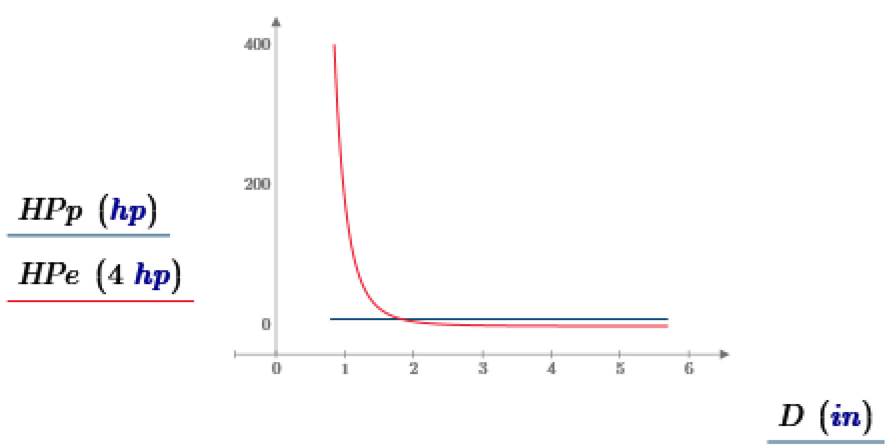
$j := 1, 2 .. 500$

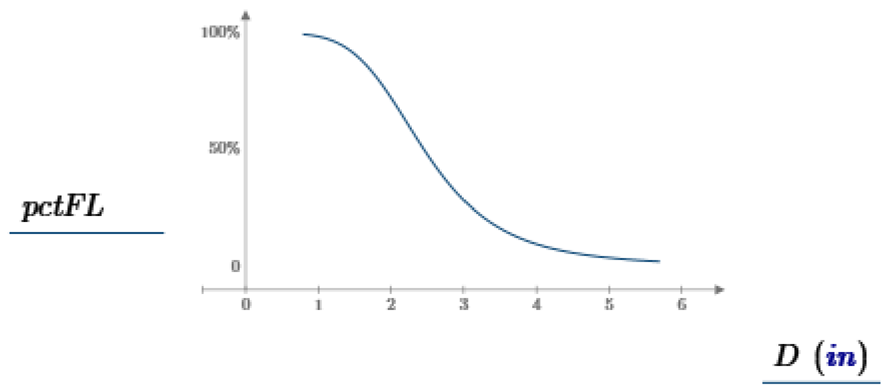
$d_j := 2 \cdot cm + \frac{j-1}{40} \cdot cm \qquad D := d \qquad V := \frac{10 \cdot m}{1200 \cdot s} \cdot \left(\frac{2 \cdot m}{D}\right)^2 \qquad Mp := (\Delta z \cdot g)$

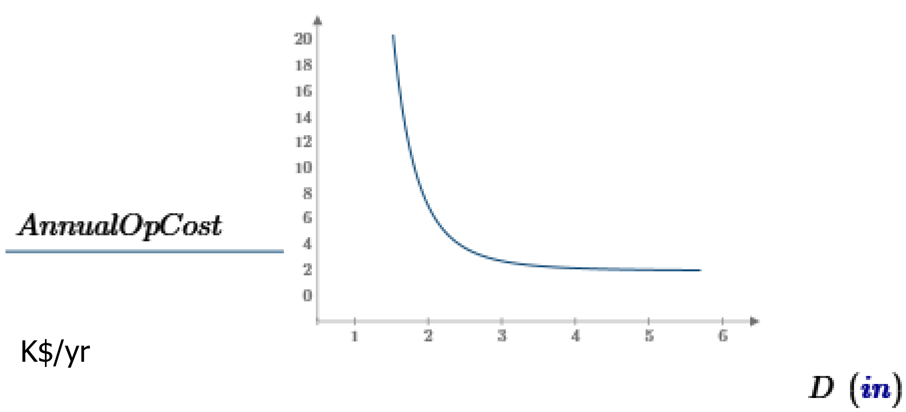
$Me_j := \left(\left(2 \cdot f \cdot \left(\frac{20 \cdot m}{D_j} + GLD + ELD\right) + \frac{1}{2} \cdot 0.5 + \frac{1}{2} \cdot (0.8 + 1)\right) \cdot {V_j}^2\right)$

$HPp_j := Mp \cdot W \quad HPe := Me \cdot W \qquad pctFL := \frac{HPe}{HPe + HPp} \qquad pctFL_{500} = 2.$

$AnnualOpCost := (HPp + HPe) \cdot 12 \cdot 365 \cdot hr \cdot C$







Engineer Economics determination of minimum Total Cost

$pct := 12\%$ $\quad n := 12$ $\quad L := 20 \cdot m$

$$A\_P := \frac{pct \cdot (1+pct)^n}{(1+pct)^n - 1} = 0.161 \qquad A\_F := \frac{pct}{(1+pct)^n - 1} = 0.041$$

Present Cost

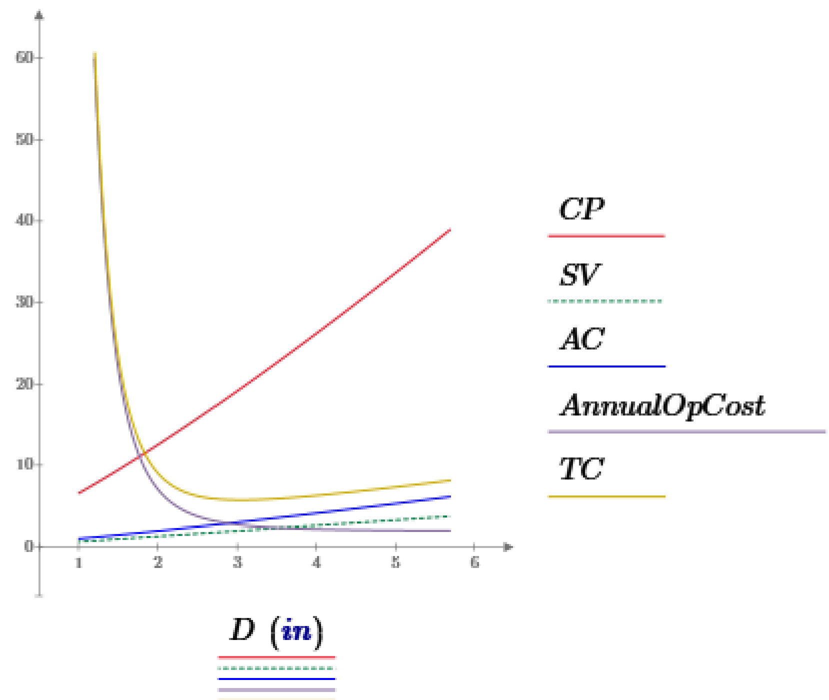
$$CP := \left(\frac{30}{ft} + \frac{70}{ft} \cdot \left(\frac{D}{1 \cdot in}\right)^{1.2}\right) \cdot \frac{L}{1000} \qquad SV := \frac{10}{ft} \cdot L \cdot \frac{D}{in} \cdot \frac{1}{1000}$$

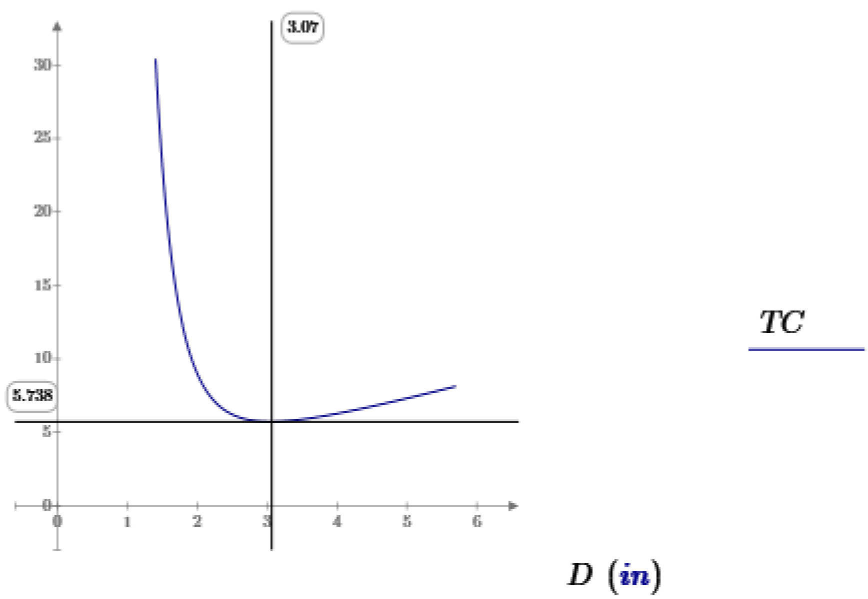
Annualized Capital Cost less SV in K$

$$AC := (CP \cdot A\_P - SV \cdot A\_F)$$

Total Cost = AC + Annual Operating Cost $\quad TC := AC + AnnualOpCost$

$$MinCost := min(TC) = 5.738$$


60
50
40
30
20
10
0
1
2
3
4
5
6
CP
SV
AC
AnnualOpCost
TC
D (in)


3.07
30
25
20
15
10
5.738
5
0
0
1
2
3
4
5
6
TC
D (in)

Find i at 3.07" (see table below): solve for i

$$d_j := 2 \cdot cm + \frac{j-1}{40} \cdot cm$$

$$J := \text{round}\left(\frac{((3.07 \cdot in - 2 \cdot cm) \cdot 40 + 1 \cdot cm)}{cm}, 0\right) = 233$$

Use J = 233 at 3" nominal Dia. pipe

$$MinAnnualCost\_At\_3\_in\_Dia := TC_J = 5.738$$

The following chart shows the relationship of the various NPS sizes and Schedules and the actual Outside Diameter and Wall Thickness.

NOMINAL PIPE SIZE	OD	SCH 5	SCH 10	SCH 40	SCH 80
1/2"	0.84	0.065	0.083	0.109	0.147
3/4"	1.05	0.065	0.083	0.113	0.154
1"	1.315	0.065	0.109	0.133	0.179
1-1/4"	1.66	0.065	0.109	0.14	0.191
1-1/2"	1.9	0.065	0.109	0.145	0.2
2"	2.375	0.083	0.109	0.154	0.218
2-1/2"	2.875	0.083	0.12	0.203	0.276
3"	3.5	0.083	0.12	0.216	0.3
3-1/2"	4	0.083	0.12	0.226	0.318
4"	4.5	0.083	0.12	0.237	0.337

REF https://www.atc-mechanical.com 3" Schedule 40 - ID=3.07"

Optimal Design Cost Summary (K$)

$$AnnualCapitalCost := AC_J = 3.084 \qquad AnnualOpCost_J = 2.654$$

$$pctCostForEnergy := \frac{AnnualOpCost_J}{AC_J + AnnualOpCost_J} = 46.3\%$$

$$pctCostForPiping := \frac{AC_J}{AC_J + AnnualOpCost_J} = 53.7\%$$

$$pctPowerForFrictionalLoss_J := pctFL_J = 26.3\%$$

$$pctPowerUsedForMovingWaterUp := 1 - pctFL_J = 73.7\%$$