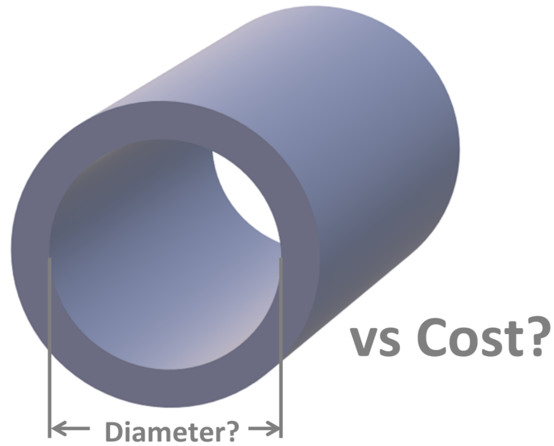
Economic Pipe Sizing

Pipework is a large part of the cost of a proces plant. Plant designer need to minimize the total cost of this pipework across the lifetime of the plant. The total overall cost is a combination of indivisual costs relating to the followings:

- Pipe material
- Installation
- Maintenance
- Depreciation
- Energy cost for pumping
- Liquid parameters
- Required flow rate
- Pumping efficiencies
- Taxes



In this application, the approach described in the reference is used to find the pipe diamenter that minimizes the total costs.

Reference: "Updating the Rules for Pipe Sizing", Durand *et al.*, Chemical Engineering, January 2010

Parameters

This application shows you the optimal solution of the pipe diamenter based on the following inputs.

Pipe Material Material := "Carbon Steel (1998)"

Note:
The following materials can be seleted besed on the implemented emperical data in this application.

- "Carbon Steel (1998)"
- "Stainless Steel (1998)"
- "Carbon Steel (2008)"
- "Stainless Steel (2008)"
- "Aluminium (2008)"
- "Brass (2008)"

Flow rate $Q := 0.557 \frac{ft^3}{s}$

Density $\rho := 62.4 \frac{lb}{ft^3}$

Viscosity $\mu := 1.0\ cPo$

Selected empirical parameters based on the material

In the code region, the datasets of empirical parameters are defined, and correct for 1998 and 2008 (as given in the reference)

Fractional annual depreciation(a) and maintenance(b) on pipeline, (a+b)	$ab := \text{Empiricaldata}(\text{Material}, \text{"ab"}) = 0.200$
Fractional annual depreciaion on pumping installation(a'), and Installed cost of pipeline, ncluding fittings (b'), (a'+b')	$ab\_dash := \text{Empiricaldata}(\text{Material}, \text{"abd"}) = 0.400$
Combined fractional efficiency of pump and motor	$E := \text{Empiricaldata}(\text{Material}, \text{"E"}) = 0.500$
Factor for installation and fitting	$F := \text{Empiricaldata}(\text{Material}, \text{"f"}) = 6.700$
Energy cost delivered to the motor	$K := \text{Empiricaldata}(\text{Material}, \text{"K"}) \frac{USD}{kWh} = 0.040 \frac{USD}{kWh}$
Factor for friction in fitting, equivalent length in pipe diameter per length of pipe	$Le := \text{Empiricaldata}(\text{Material}, \text{"Led"}) \frac{1}{ft} = 2.740 \frac{1}{ft}$
Exponent in pipe-cost equation	$n := \text{Empiricaldata}(\text{Material}, \text{"n"}) = 1.350$
Installation cost of pump and motor	$P := \text{Empiricaldata}(\text{Material}, \text{"P"}) \frac{USD}{hp} = 150 \frac{USD}{HP}$
Cost of 1ft of 1ft diameter pipe	$X := \text{Empiricaldata}(\text{Material}, \text{"X"}) USD = 29.520\ USD$
Days of operation per year (at 24 hours per day)	$Y := \text{Empiricaldata}(\text{Material}, \text{"Y"}) day = 365\ d$
Fractional rate of return of incremental investment	$Z := \text{Empiricaldata}(\text{Material}, \text{"Z"}) = 0.100$
Factor for taxes and other expenses	$\Phi := \text{Empiricaldata}(\text{Material}, \text{"Phi"}) = 0.550$
Factor to express cost of piping installation, in terms of yearly cost of power delivered to the fluid	$M := \dfrac{ab\_dash \cdot E \cdot \left(\frac{P}{\frac{USD}{HP}}\right)}{17.9 \cdot \left(\frac{K}{\frac{USD}{kWh}}\right) \cdot \left(\frac{Y}{day}\right)} = 0.115$

Economical Pipe size

The economical optimal pipe diamenter (as given in the reference) is given by an iterative solution of the following equation, called as Generaux equation.
In the following calculation, fsolve() function is called to obtain the solution of the objective.

Objective function

$$Obj := \frac{Q}{\frac{ft^3}{s}} = \left(\frac{D^{4.84+n} \cdot n \cdot \left(\frac{X}{USD}\right) \cdot E \cdot (1+F) \cdot (Z + (ab) \cdot (1-\Phi))}{\left(1 + 0.794 \cdot \left(\frac{Le}{\frac{1}{ft}}\right) \cdot D\right) \cdot \left(0.000189 \cdot \left(\frac{Y}{d}\right) \cdot \left(\frac{K}{\frac{USD}{kWh}}\right) \cdot \left(\frac{\rho}{\frac{lb}{ft^3}}\right)^{0.84} \cdot \left(\frac{\mu}{cPo}\right)^{0.16}\right) \cdot \left((1+M) \cdot (1-\Phi) + \frac{Z \cdot M}{ab\_dash}\right)} \right)^{\frac{1}{2.84}}$$

Optimized pipe diameter

$$D_{optimal} := fsolve(Obj)\,ft = 0.293\,ft$$

Fluid velocity

$$v_{optimal} := \frac{Q}{\pi \cdot \left(\frac{D_{optimal}}{2}\right)^2} = 8.253\,\frac{ft}{s}$$