Economic Pipe Sizing

Parameters		Economic Pipe Size	
Pipe Material	Stainless Steel (1998)	Diameter (in)	2.532
Flowrate ($ft^3\ s^{-1}$)	0.557	Fluid velocity ($ft\ s^{-1}$)	15.931
Density ($lb\ ft^{-3}$)	62.4		
Viscosity (cp)	1		

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

Background

Pipework is a large part of the cost of a process plant. Plant designers need to minimize the total cost of this pipework across the lifetime of the plant. The total overall cost is a combination of individual costs relating to the

- pipe material,
- installation,
- maintenance,
- depreciation,
- energy costs for pumping,
- liquid parameters,
- required flowrate,
- pumping efficiencies,
- taxes,
- and more.

This application uses the approach described in the reference to find the pipe diameter that minimizes the total overall cost. The method involves the iterative solution of an empirical equation using Maple's fsolve() function (the code is in the Startup code region)

Bear in mind that the empirical parameters vary as economic conditions change. Those used in this application are correct for 1998 and 2008 (as given in the reference)

The economical optimal pipe diameter (as given in the reference) is given by an iterative solution of the following equation (Generaux Equation).

$$Q = \left(\frac{D^{4.84+n} n X E (1+F) \left(Z + (a+b) \cdot (1-\Phi) \right)}{(1+0.794\, Le' D) \left(0.000189\, Y K \rho^{0.84} \mu^{0.16} \right) \left((1+M)(1-\Phi) + \frac{Z \cdot M}{a'+b'} \right)} \right)^{\frac{1}{2.84}}$$

where the empirical parameters are

	n	X	Le'	M	E	P	K	Y	Phi	Z	f	a+b	a'+b'
Carbon Steel (1998)	1.35	29.52	2.74	0.102	0.5	150	0.04	365	0.55	0.1	6.7	0.2	0.4
Stainless Steel (1998)	0.7793	130	2.74	0.102	0.5	150	0.04	365	0.55	0.1	7.5	0.2	0.4
Carbon Steel (2008)	1.472	6.607	2.74	0.064	0.5	150	0.07	365	0.55	0.1	6.5	0.2	0.4
Stainless Steel (2008)	0.924	30.7	2.74	0.064	0.5	150	0.07	365	0.55	0.1	7.4	0.2	0.4
Aluminium (2008)	0.769	22.26	2.74	0.064	0.5	150	0.07	365	0.55	0.1	7.1	0.2	0.4
Brass (2008)	0.907	32.3	2.74	0.064	0.5	150	0.07	365	0.55	0.1	7.2	0.2	0.4

and

a	Fractional annual depreciation on pipeline (dimensionless)
b	Fractional annual maintenance on pipeline (dimensionless)
a'	Fractional annual depreciation on pumping installation (dimensionless)
b'	Installed cost of pipeline, including fittings ($/ft)
C	Inside pipe diameter (ft)
D	Inside pipe diameter (ft)
E	Combined fractional efficiency of pump and motor (dimensionless)
F	Factor for installation and fitting
K	Energy cost delivered to the motor ($/kWh)
Le'	Factor for friction in fitting, equivalent length in pipe diameter per length of pipe (1/ft)
M	

n	Exponent in pipe-cost equation $C = X D^n$ (dimensionless)
P	Installation cost of pump and motor ($/hp)
Q	Fluid flowrate (ft^3/s)
S	Cross sectional area (ft^2)
V	Velocity (ft/s)
X	Cost of 1 ft of 1 ft diameter pipe ($)
Y	Days of operation per year (at 24 hours per day)
Z	Fractional rate of return of incremental investment (dimensionless)
Φ	Factor for taxes and other expenses (dimensionless)
ρ	Flow density (lb/ft^3)
μ	Fluid viscosity (cP)

	$\frac{(a'+b')\ (EP)}{17.9\,KY}$ Factor to express cost of piping installation, in terms of yearly cost of power delivered to the fluid (dimensionless)		