CALCULATION OF ECONOMIC PIPE DIAMETER

by

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Using the continuity equation Q = VA and taking into consideration the acceptable velocity and pressure drop across the pipeline will enable one to quickly determine the size of pipeline. However, to determine the most economical pipe size with reasonable accuracy, a more comprehensive method is required. This article aims to demonstrate the calculation method using the example below on how to determine the most economical pipe size. Please note: the values herein are arbitrary results and users are recommended to perform their own due diligence to determine what those values are.

Step 1: Pressure drop

Information Available	
Flowrate	200 $Lmin^{-1}$ (0.00333 m^3s^{-1})
Total length of pipeline	200 m
Elevation of pipe (Rise)	5 m
Pipe type	SS316, Sch 40
Water properties at 20°C	
Density	998 kgm^{-3}
Dynamic viscosity	0.001 Pa.s ($kgm^{-1}s^{-1}$)
No. of pipe fittings	
Full-bore ball valve	5
Global valve	1
Standard 90° bend	4

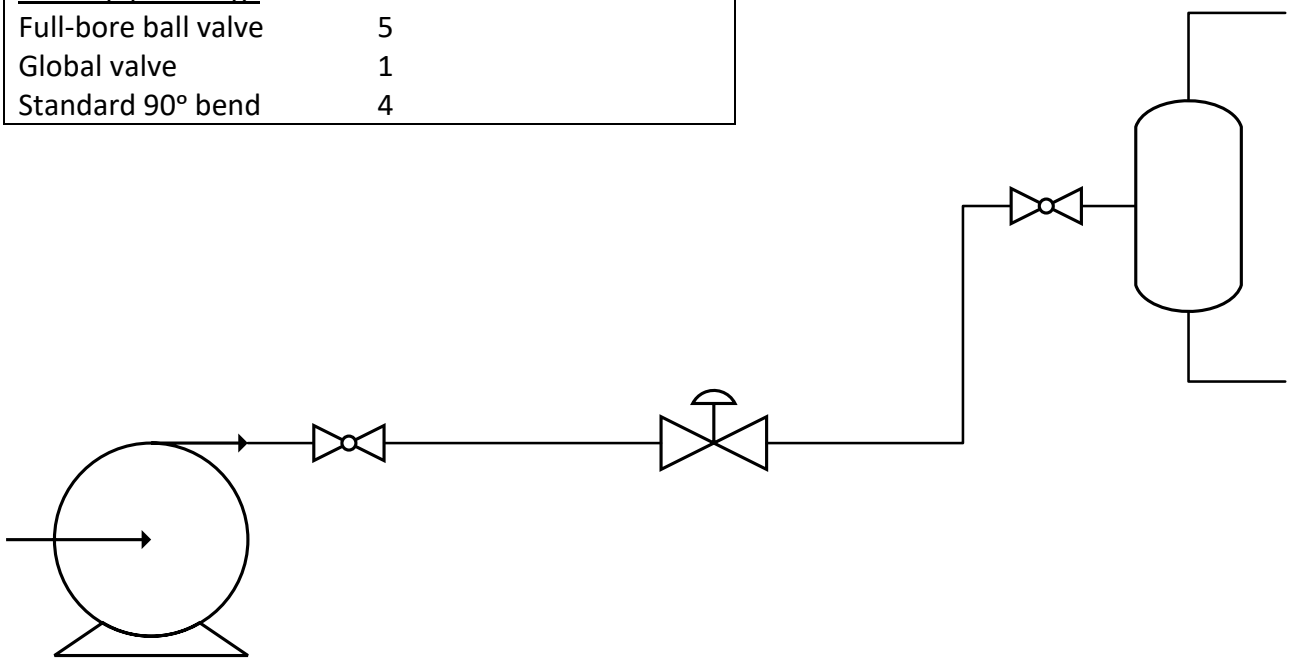


Table 1: Calculated pressure drop

Nominal Pipe Diameter, NB	Velocity, ms^{-1}	Pressure Drop, kPa
25	5.978	3388.7
40	2.538	428.1
50	1.540	158.1
80	0.699	64.8

Step 2: Pumping cost

Data Available	
Cost of power	$ 0.12 per kWhr
Combine pump-drive efficiency	65 %
Pump duty	24 hrs per day, 365 days per year
Interest rate	10%
Power cost escalation rate	2%
Pipeline design life	15 years

The annual pumping cost is given as:

$$Y = \frac{Q \times \rho \times g \times \varepsilon_p \times C \times T}{\eta_{pm} \times 1000} \quad (1)$$

Where:

Y : annual pumping cost, $ per year
Q : volumetric flowrate, m^3s^{-1}
ρ : liquid density, kgm^{-3}
g : gravitational acceleration, ms^{-2}
ε_p : head added by the pump, m
C : cost of power, $ per kWhr
T : total hours pumped per year, hr per year
η_{pm} : combined efficiency of pump and drive

$$\varepsilon_p = \frac{P}{\rho g} \quad (2)$$

Present value of annuity is given as:

$$PVA = \frac{Y(1-(1+j)^{-n})}{j} \quad (3)$$

Where:

PVA : present value of annuity, $
Y : annual pumping cost, $ per year
i : annual interest rate (as decimal)
n : number of years
m : rate of escalation of annual power cost (as decimal)
j : $\frac{i-m}{1+m}$

Step 3: Capital cost for pipe installation

Data Available				
Nominal Pipe Diameter, NB	25	40	50	80
Installation cost, $ per metre	121	135	175	250

Step 4: Total present value

$$\text{Total Present Value} = Capital\ Cost + PVA \tag{4}$$

Sample calculation for 25NB pipe

From (2),

$$\varepsilon_p = \frac{3388.7 \times 10^3 Pa}{998 kgm^{-3} \times 9.81 ms^{-2}} = 346.13m$$

For 25 NB pipe, the pump must be able to overcome the pressure drop of 3388.7 kPa, that is, it must be able to deliver 346.13 m.

From (1),

$$Y = \frac{0.00333 m^3 s^{-1} \times 998 kgm^{-3} \times 9.81 ms^{-2} \times 346.13m \times \$0.12 kWhr \times \left(24 \frac{hrs}{day} \times 365 \frac{days}{year}\right)}{0.65 \times 1000}$$

$$= \$18{,}268\ per\ year$$

From (3)

$$j = \frac{0.1 - 0.02}{(1 + 0.02)} = 0.0784$$

$$PVA = \frac{18{,}268(1 - (1 + 0.0784)^{-15})}{0.0784} = \$157{,}871$$

$$Capital\ cost\ of\ pipeline = \$121\ per\ metre \times 200m = \$24{,}200$$

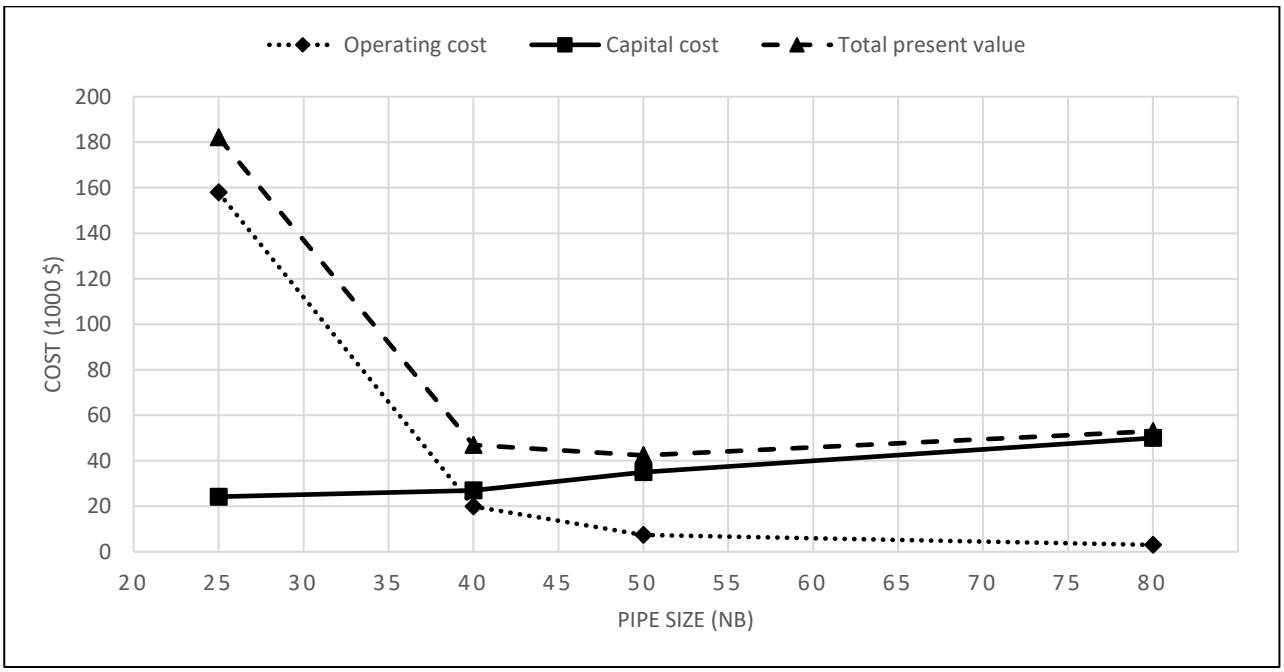
From (4)

$$\text{Total Present Value} = \$24{,}200 + \$157{,}871 = \$182{,}071$$

Step 5: Cost comparison

In summary,

Nominal Pipe Diameter, NB	25	40	50	80
Y, $ per year	18,268	2,308	852	349
PVA, $	157,871	19,944	7,365	3,019
Capital Cost, $	24,200	27,000	35,000	50,000
Total Present Value, $	182,071	46,944	42,365	53,019
Selected pipe diameter			✓	



The summary of results show that although using the smaller nominal bore pipe presents the lowest capital cost, the operating cost is the highest thereby resulting in excessive total present value. In contrast, using largest pipe may result in a lower operating cost but at the expense of a higher capital cost. Hence, after considering the installation cost of pipe and pump operating cost throughout its design life, the 50 NB pipe is selected as the most economical pipe diameter.

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