Fluid Mechanics - Course 223

MINOR LOSSES

These are losses which occur in pipelines, due to bends, elbows, joints, valves, etc and are called 'minor losses'. This is a misnomer, because in many situations the minor losses are more significant than the losses due to pipe friction, which we have already considered.

We have already seen, in level 3, that the pressure energy loss varies as the square of the velocity. This is basically true for all minor losses in turbulent flow. Sudden contractions in area also cause losses, as in entrances and exits from pipework.

Minor losses are accounted for, by considering the equivalent length of pipework which would give the same pressure loss.

$$E_{LOSS} = f\,\frac{LV^2}{2D} = K\,\frac{V^2}{2} \quad \text{where } \frac{V^2}{2} = KE$$

K = dimensionless coefficient

Thus $L = \frac{KD}{f}$

'K' is quoted for various fittings as shown in Table 4.1.

By considering all the fittings that are involved, the various coefficients may be added together to give a total equivalent value of 'K'. This value may be substituted into $L = \frac{KD}{f}$ to determine the equivalent length of pipe, that is equal to the resistance of the fittings.

Some tables quote the friction effect of the fittings as an equivalent length in pipe diameters.

<u>Example</u>

A 90° Standard Elbow has an L/D ratio of 30. If the pipe is 16" then the equivalent length = $30 \times \frac{16}{12}$

$= \underline{40\ ft}$

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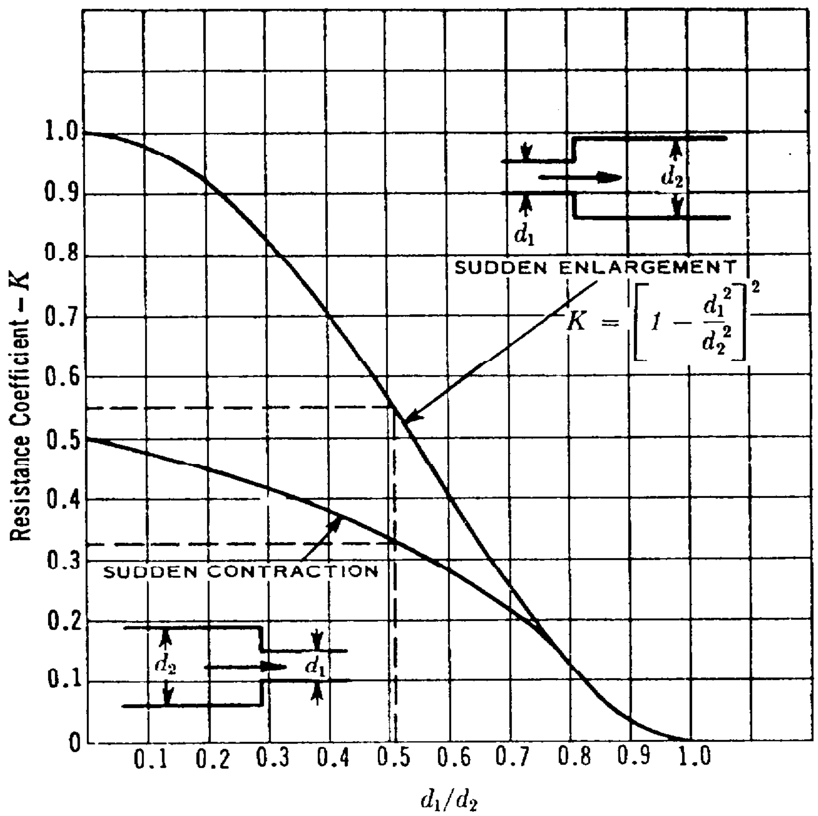
TABLE 4.1

LOSS COEFFICIENTS FOR COMMERCIAL PIPE FITTINGS

Fitting	'K'
Globe valve, fully open	10
Angle valve, fully open	5
Swing check valve, fully open	2.5
Closed return bend	2.2
Tee, through side outlet	1.8
Short radius elbow	0.9
Medium radius elbow	0.8
Long radius elbow	0.6
45-degree elbow	0.4
Gate valve, fully open	0.2
Gate valve, 3/4 open	1
Gate valve, 1/2 open	5.6
Gate valve, 1/4 open	24

TABLE 4.2

Resistance Due to Sudden Enlargements and Contractions[20]



Sudden enlargement: The resistance coefficient K for a sudden enlargement from 6-inch Schedule 40 pipe to 12-inch Schedule 40 pipe is 0.55, based on the 6-inch pipe size.

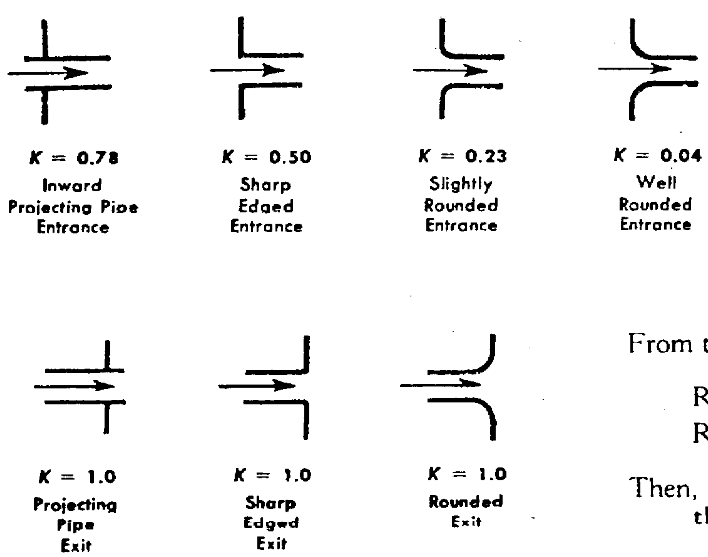
$$\frac{d_1}{d_2} = \frac{6.065}{11.938} = 0.51$$

Sudden contraction: The resistance coefficient K for a sudden contraction from 12-inch Schedule 40 pipe to 6-inch Schedule 40 pipe is 0.33, based on the 6-inch pipe size.

$$\frac{d_1}{d_2} = \frac{6.065}{11.938} = 0.51$$

Note: The values for the resistance coefficient, K, are based on velocity in the small pipe. To determine K values in terms of the greater diameter, multiply the chart values by $(d_2/d_1)^4$.

Resistance Due to Pipe Entrance and Exit



Problem: Determine the total resistance coefficient for a pipe one diameter long having a sharp edged entrance and a sharp edged exit.

Solution: The resistance of pipe one diameter long is small and can be neglected ($K = f\, L/D$).

From the diagrams, note:

Resistance for a sharp edged entrance = 0.5
Resistance for a sharp edged exit = 1.0

Then,
the total resistance, K, for the pipe = 1.5

TABLE 4.3

Schedule (Thickness) of Steel Pipe Used in Obtaining Resistance Of Valves and Fittings of Various Pressure Classes by Test*

Valve or Fitting ASA Pressure Classification (Steam Rating)		Schedule No. of Pipe (Thickness)
250-Pound and Lower		Schedule 40
300-Pound to 600-Pound		Schedule 80
900-Pound		Schedule 120
1500-Pound		Schedule 160
2500-Pound	Sizes ½ to 6-inch	xx (Double Extra Strong)
	Sizes 8-inch and larger	Schedule 160

*These schedule numbers have been arbitrarily selected only for the purpose of identifying the various pressure classes of valves and fittings with specific pipe dimensions for the interpretation of flow test data; they should not be construed as a recommendation for installation purposes.

Representative Equivalent Length‡ in Pipe Diameters (L/D) Of Various Valves and Fittings

Description of Product				Equivalent Length In Pipe Diameters (L/D)
Valves	Conventional Globe	With no obstruction in flat, bevel, or plug type seat	Fully open	340
		With wing or pin guided disc	Fully open	450
	Y-Pattern Globe	With stem 60 degrees from run of pipe line	Fully open	175
		With stem 45 degrees from run of pipe line	Fully open	145
	Conventional Angle	With no obstruction in flat, bevel, or plug type seat	Fully open	145
		With wing or pin guided disc	Fully open	200
	Conventional Wedge Disc, Double Disc, or Plug Gate		Fully open	13
			Three-quarters open	35
			One-half open	160
			One-quarter open	900
	Pulp Stock Gate		Fully open	17
			Three-quarters open	50
			One-half open	260
			One-quarter open	1200
	Conduit Pipe Line Gate		Fully open	3**
	Butterfly (6-inch and larger)		Fully open	20
	Conventional Swing Check		0.5† . . . Fully open	135
	Clearway Swing Check		0.5† . . . Fully open	50
	Globe Lift Check or Stop-Check		2.0† . . . Fully open	Same as Conv. Globe
	Angle Lift Check or Stop-Check		2.0† . . . Fully open	Same as Conv. Angle
	Foot Valves	With strainer and poppet lift-type disc	0.3† . . . Fully open	420
		With strainer and leather-hinged disc	0.4† . . . Fully open	75
	In-Line Ball Check	2.5 vertical and 0.25 horizontal†	Fully open	150
Straight-Through Cocks		Rectangular plug port area equal to 100% of pipe area	Fully open	18
Three-Way Cocks		Rectangular plug port area equal to 80% of pipe area (fully open)	Flow straight through	44
			Flow through branch	140
Fittings	90 Degree Standard Elbow			30
	45 Degree Standard Elbow			16
	90 Degree Long Radius Elbow			20
	90 Degree Street Elbow			50
	45 Degree Street Elbow			26
	Square Corner Elbow			57
	Standard Tee	With flow through run		20
		With flow through branch		60
	Close Pattern Return Bend			50
Pipe	90 Degree Pipe Bends			See Page A-27
	Miter Bends			See Page A-27
	Sudden Enlargements and Contractions			See Page A-26
	Entrance and Exit Losses			See Page A-26

**Exact equivalent length is equal to the length between flange faces or welding ends.

†Minimum calculated pressure drop (psi) across valve to provide sufficient flow to lift disc fully.

‡For limitations, see page 2-11.

For resistance factor "K", equivalent length in feet of pipe, and equivalent flow coefficient "C_v", see pages A-31 and A-32.

Example

If the fittings, in a 12" pipeline have a total resistance coefficient K = 20 and if f = 0.02 for the line, then the equivalent length of the fitting may be added to the actual length of the line as below:

$$\text{Equivalent Length } L = \frac{KD}{f} = \frac{20 \times 1}{0.02} = 1{,}000 \text{ ft}$$

Problems involving pressure losses have a basic solution pattern:

(a) Determine the Reynolds' No.

(b) Use the R_E to find 'f', the friction factor.

(c) Determine 'K' for all the fittings and evaluate an equivalent length, including entrance and exit losses.

(d) Use E_{LOSS} = 'f' $\frac{LV^2}{2D}$ to obtain total loss.

Example

A 10" SCH 40 pipe is 100 m, and carries oil at 0.3 m^3/s. Density = 850 kg/m^3 and $\mu = 1 \times 10^{-1}$ ns/m^2. The line is fitted with a swing check valve, which is fully open at the inlet and a gate valve which is fully open at the outlet.

Calculate:

(a) The pressure drop in the line.

(b) The power required.

$$\text{Velocity} = \frac{\text{flowrate}}{\text{area}} = \frac{0.3}{508.7 \times 10^{-4}} = \underline{5.9} \text{ m/s}$$

$$R_E = \frac{VD\ell}{\mu} = \frac{5.9 \times 10 \times 2.54 \times 10^{-2} \times 850}{1 \times 10^{-1}}$$

$$= \underline{12{,}738}$$

E/D from Chart 1 - 0.00018

f from Chart 2 = 0.029

K for swing check valve = 2.5
gate valve = $\underline{0.19}$
$\underline{2.69}$

Thus equivalent length $= \frac{KD}{f}$

$$= \frac{2.69 \times 10 \times 2.54 \times 10^{-2}}{0.029}$$

$$= \underline{23.6 \text{ m}}$$

$E_{LOSS} = \frac{fLV^2}{2D}$ where $L = 100 + 23.6$

$$= \underline{123.6 \text{ m}}$$

$$= \frac{0.029 \times 123.6 \times 5.9^2}{2 \times 10 \times 2.54 \times 10^{-2}}$$

$= 246$ J/kg = Pressure Energy

Pressure Energy $= \frac{P}{\ell}$ $\frac{J}{kg}$

Thus $\Delta P = 246 \times 850$ Pa

$\Delta P = \underline{209.1 \text{ kPa}}$

Power required $= Q_m \times E_{LOSS}$

$$= Q_V \times \ell \times E_{LOSS}$$

$$= \frac{m^3}{s} \times \frac{kg}{m^3} \times \frac{J}{kg} = \frac{J}{s} = w$$

$$= 0.3 \times 850 \times 246$$

$$= \underline{62.73} \text{ kw}$$

ASSIGNMENT

1. What are minor losses and why are they important?
2. How are minor losses calculated.
3. A line is fitted with a plug seat globe valve, a conventional swing check valve, 5 x 90° standard elbows and a standard tee with flow through the branch. If the line is 10" diameter, what is the effective length due to the resistance of the fittings?

4. A pump provides 60 kw to pump water along a 12" pipe at 0.4 m^3/s. The line is fitted with four medium standard 90° elbows and a swing check valve. What is the longest length of line that may be used to satisfy these conditions and what is the pressure drop? (ℓ = 998 kg/m^3; $\gamma = 1.007 \times 10^{-6}$ m^2/s)

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