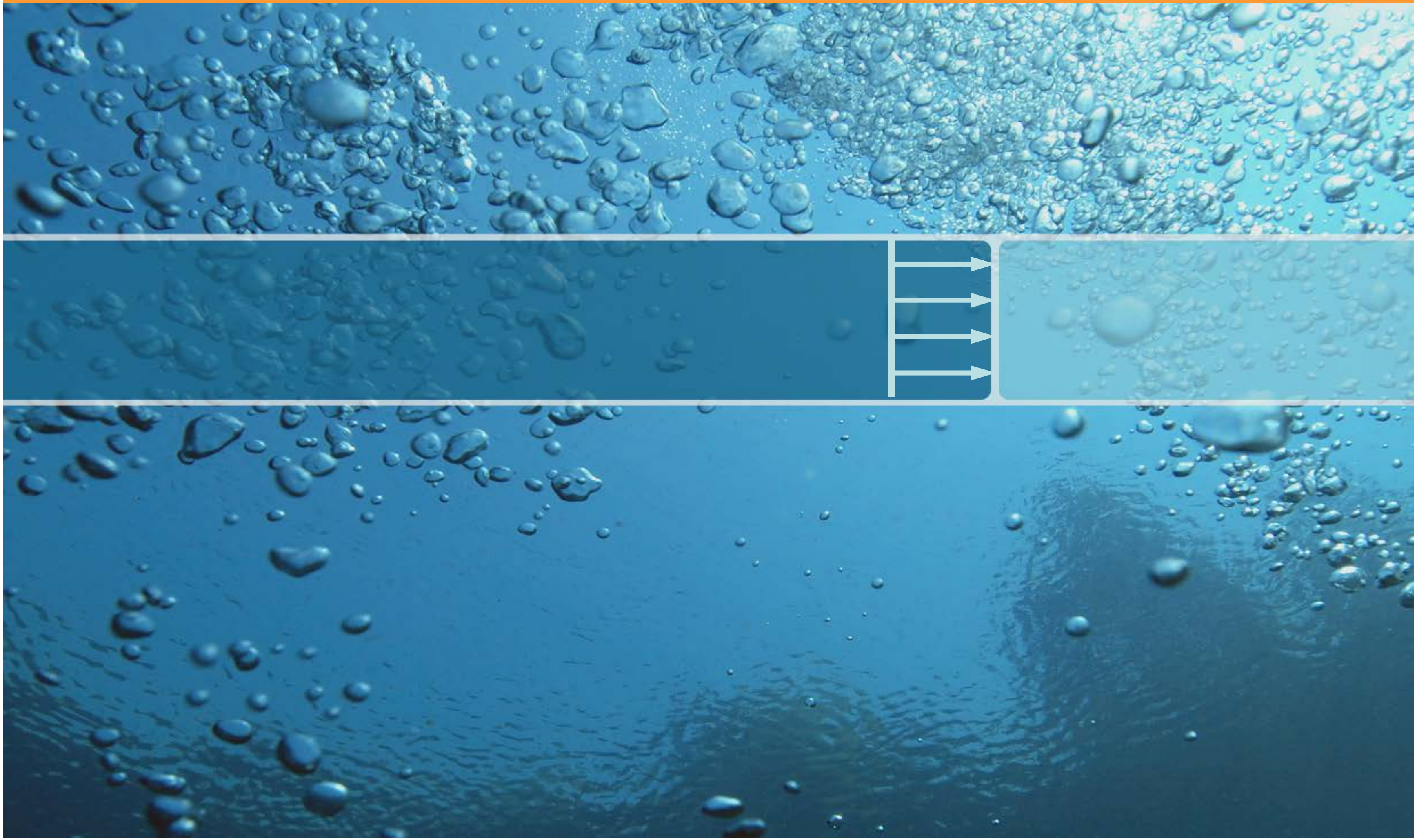
ME444 ENGINEERING PIPING SYSTEM DESIGN

CHAPTER 4 : FLOW THEORY

CONTENTS

1. CHARACTERISTICS OF FLOW

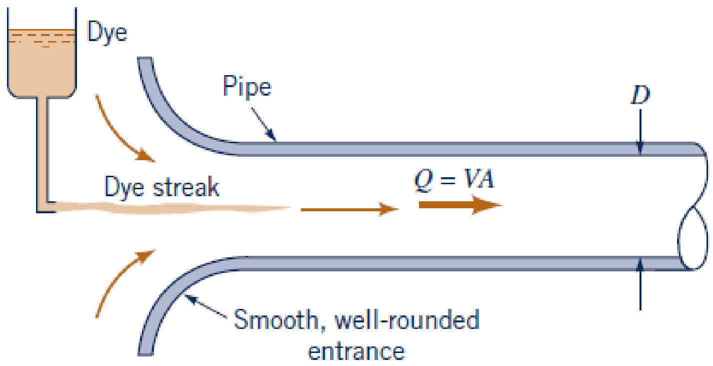


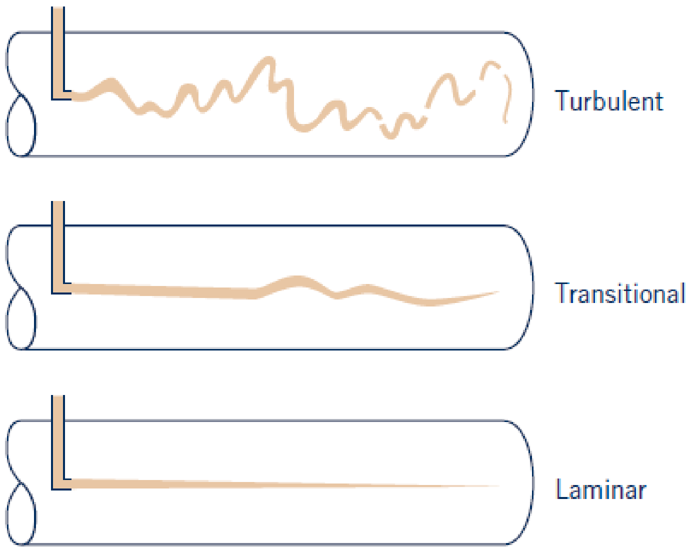
WATER AT 20°C

Properties	Symbols	Values
Density	ρ	998.2 kg/m^3
Viscosity (Absolute)	μ	1.002 x 10^{-3} N.s/m^2
Viscosity (Kinematic)	$\nu = \mu / \rho$	1.004 x 10^{-6} m^2/s

Reynold’s Experiment

Osborne Reynolds (1842-1912) systematically study behavior of by injecting color in to a glass tube which has water flow at different speed





Reynold’s Experiment

Reynold's Number

$$\mathrm{Re} = \frac{\rho v D}{\mu} = \frac{vD}{\nu}$$

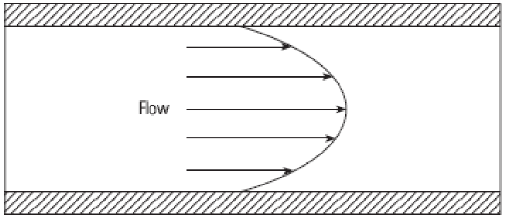
← Inertia effect

← Viscous effect

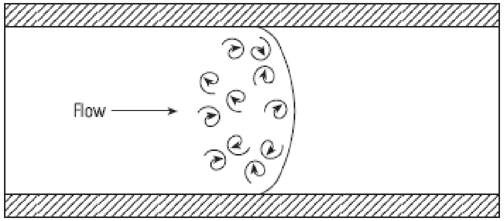
Inertia effect leads to chaos → Turbulent

Viscous effect holds the flow in order → Laminar

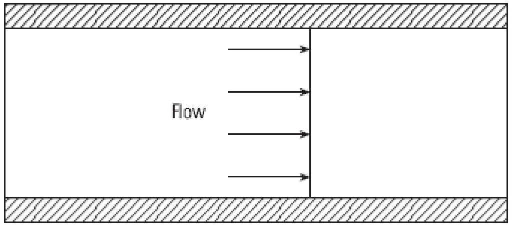
Flow Patterns



Laminar (Re < 2300)

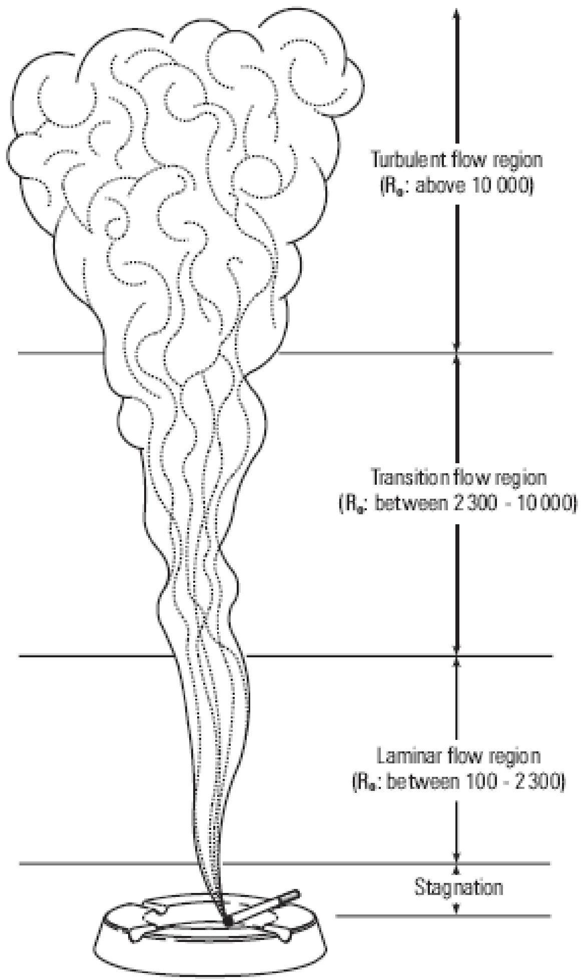


Turbulent (Re >10,000)



Non-viscous

Flow Patterns



Re of flow in pipe

Low velocity flow in a DN20 SCH40 pipe at 1.2 m/s (25 lpm)

$$\mathrm{Re} = \frac{vD}{\nu} = \frac{\left(1.2 m/s\right)\cdot\left(20.93\times10^{-3} m\right)}{\left(1.004\times10^{-6} m^2/s\right)} = 25{,}016$$

TURBULENT

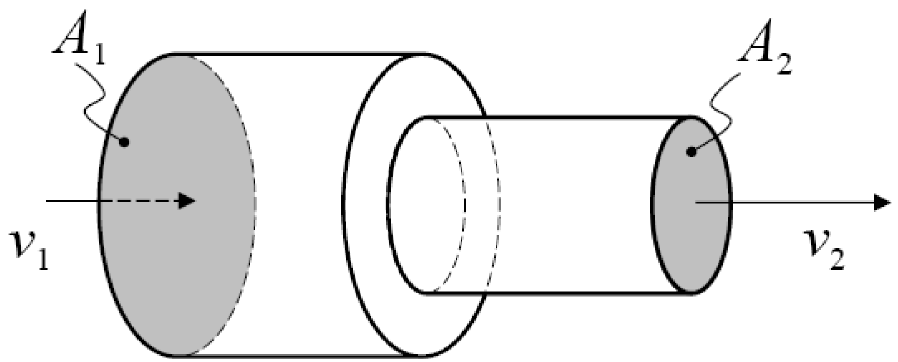
2. BASIC EQUATIONS

CONSERVATION OF MASS

ENERGY EQUATION

MOMENTUM EQUATION

CONSERVATION OF MASS



MASS FLOW IN = MASS FLOW OUT: $\rho_1 Q_1 = \rho_2 Q_2$

INCOMPRESSIBLE FLOW: $A_1 v_1 = A_2 v_2 = Q$

ENERGY EQUATION

ENERGY IN FLUID IN JOULE / M^3 IS

POTENTIAL ENERGY IN ELEVATION $\rho g z$

POTENTIAL ENERGY IN PRESSURE p

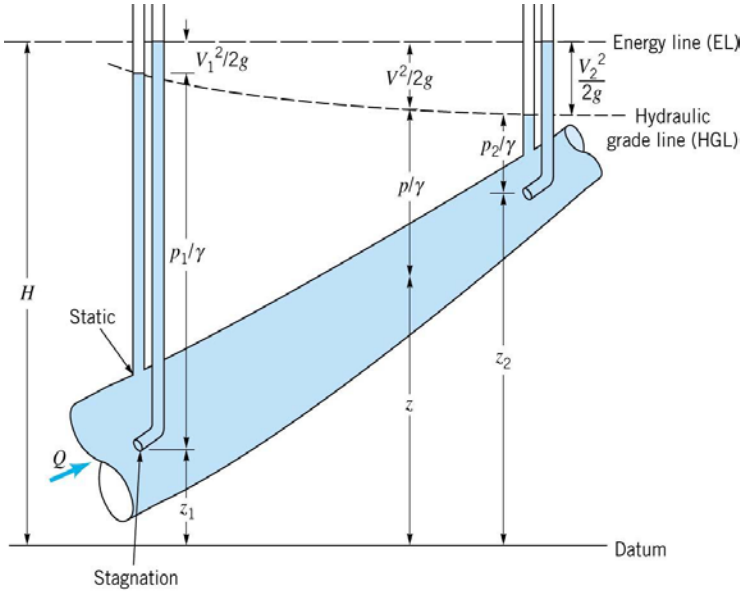
KINETIC ENERGY $\dfrac{\rho v^2}{2}$

HEIGH UNIT IS MORE PREFERABLE → **HEAD**

DIVIDE THE ABOVES WITH ρg

HEAD

Total head = Static pressure head + Velocity head + Elevation



$$z_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_L$$

ENERGY IS NOT CONSERVED

GUAGE PRESSURE

ATMOSPHERIC PRESSURE IS
1 ATM = 1.013 BAR = 10.33 m. WATER

EVERYWHERE
(AT SEA LEVEL)

(1 BAR = 10.2 m. WATER)

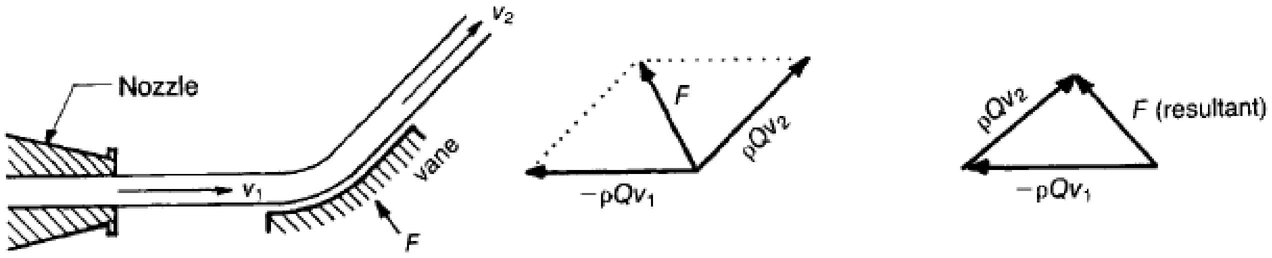
GAUGE PRESSURE IS MORE PREFERABLE IN LIQUID FLOW

$$p_{guage} = p_{abs} - p_{atm}$$

GAUGE PRESSURE IS MORE PREFERABLE IN LIQUID FLOW

USUALLY CALLED m.WG., psig, barg

MOMENTUM EQUATION

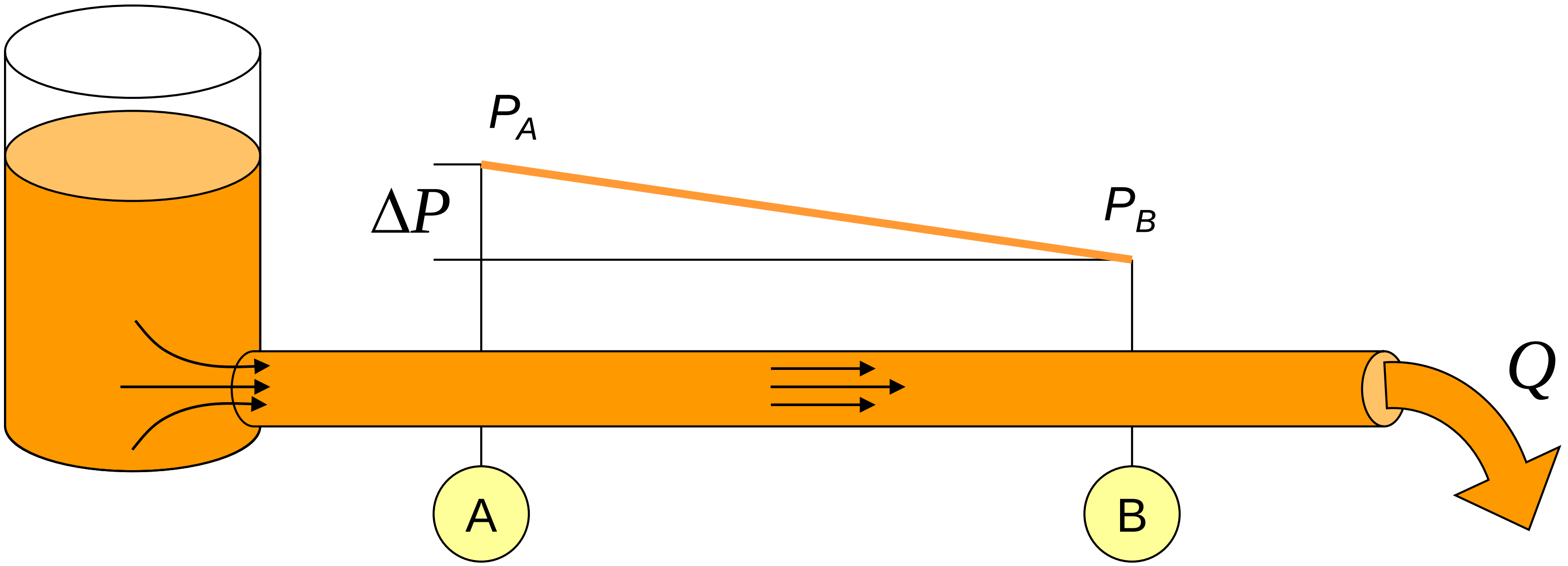


$$\vec{F} = m\frac{d\vec{v}}{dt} = \rho Q \Delta \vec{v} = \rho Q\left(\vec{v}_2 - \vec{v}_1\right)$$

LOSS

MAJOR LOSS: LOSS IN PIPE

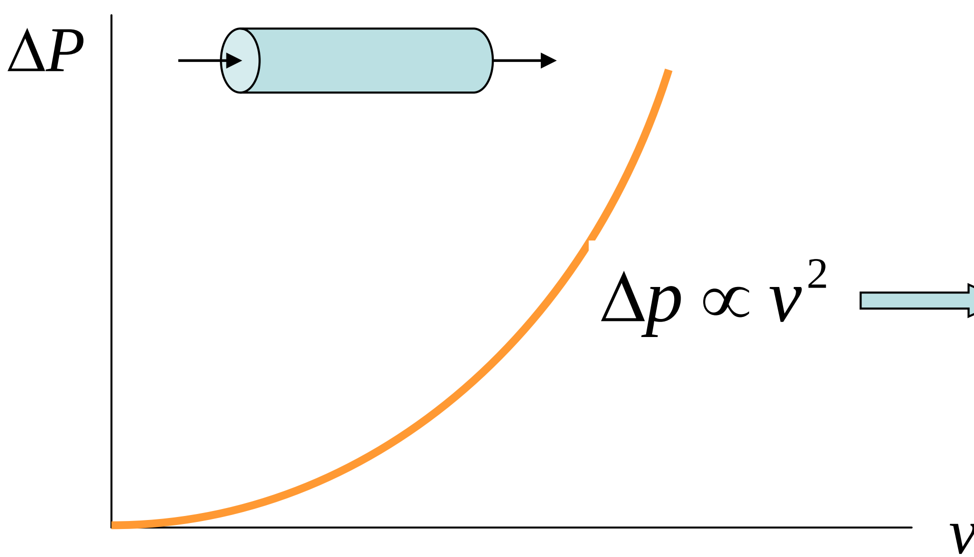
MINOR LOSS: LOSS IN FITTINGS AND VALVES



LOSS IN PIPE

PRESSURE DROP IN PIPE IS A FUNCTION OF

FLUID PROPERTIES (DENSITY AND VISCOSITY)
ROUGHTNESS OF PIPE
PIPE LENGTH
PIPE INTERNAL DIAMETER }
FLOW VELOCITY } **FLOWRATE**



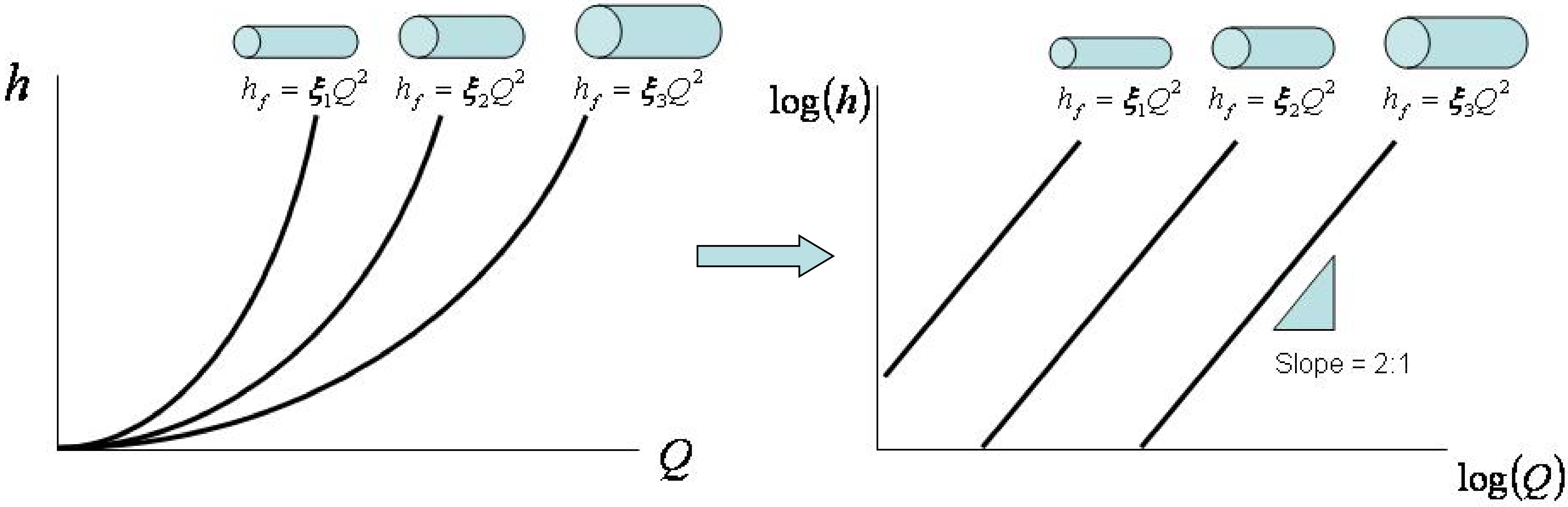
$$\Delta p \propto v^2 \;\Longrightarrow\; v = \frac{Q}{\left(\frac{\pi D^2}{4}\right)} \;\Longrightarrow\; \Delta P \propto Q^2$$

$$\frac{\Delta P}{\rho g} = h_f = \xi Q^2$$

HEAD LOSS IN PIPE

$$h_f = \xi Q^2$$

ξ varies mainly with pipe size, pipe roughness and fluid viscosity



DARCY-WEISSBACH EQUATION

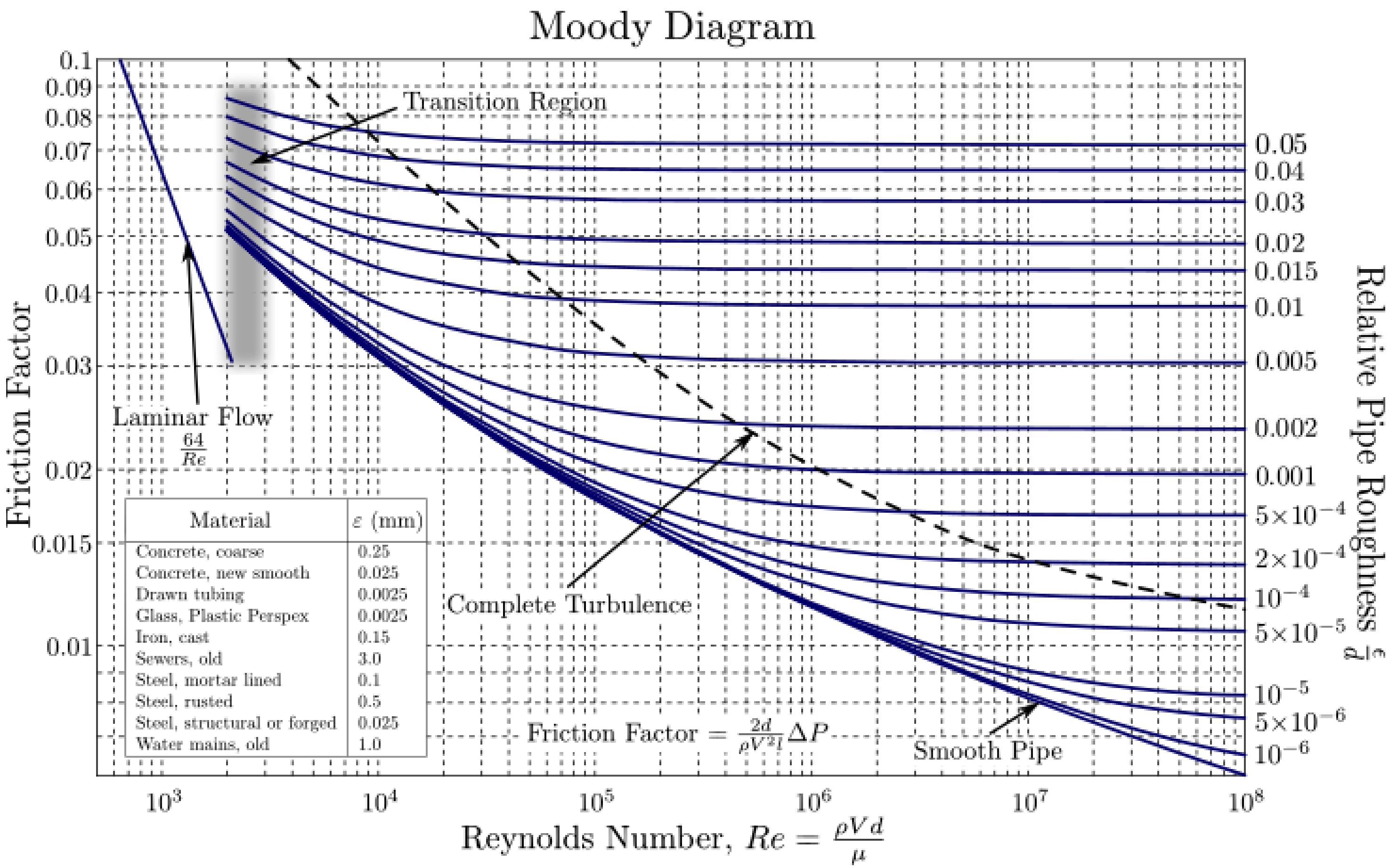
$$h_f = f\frac{L}{D}\frac{v^2}{2g}$$

$$h_f = \xi Q^2$$

$$\xi = \frac{8Lf}{\pi^2 D^5 g}$$

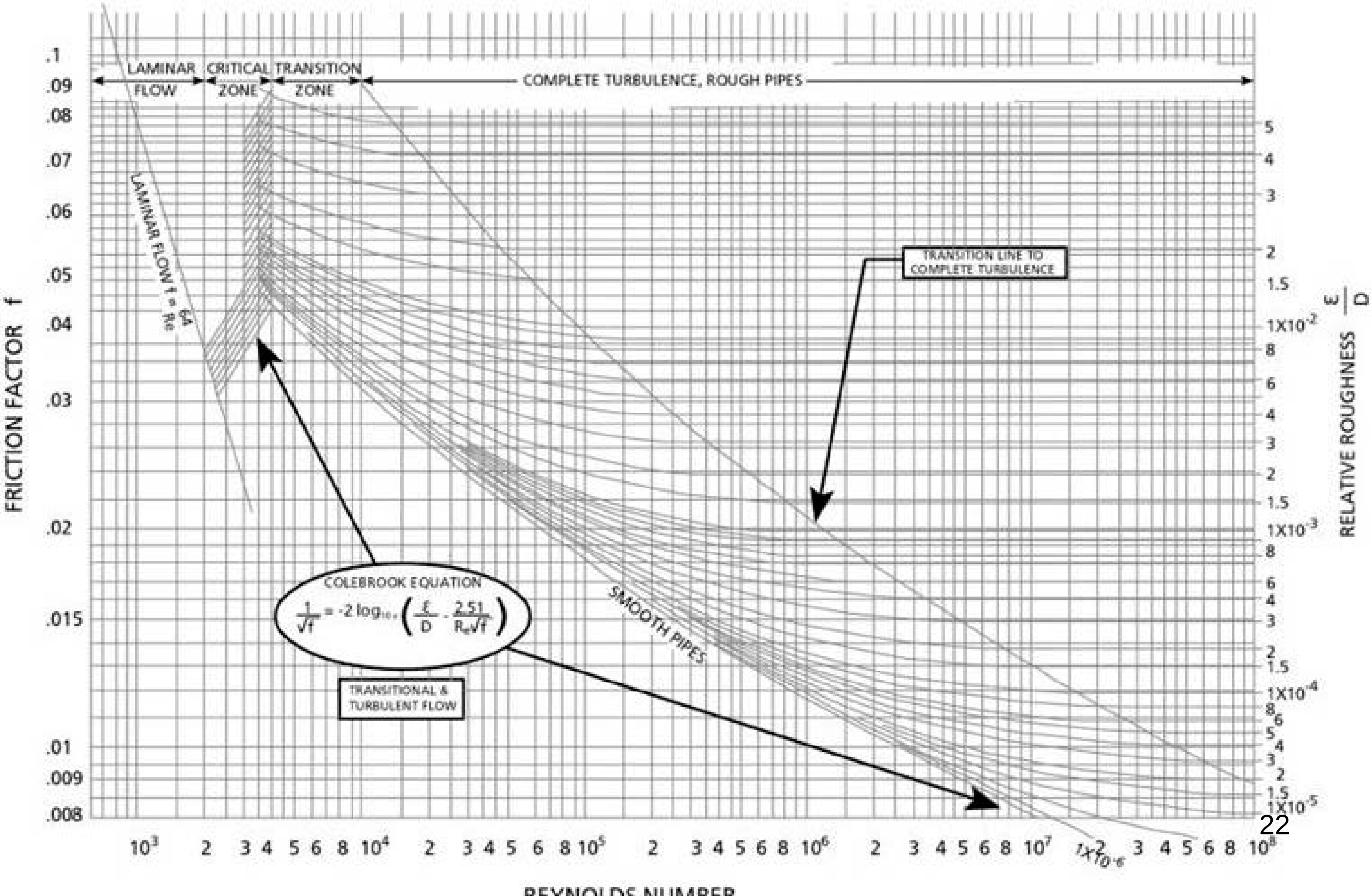
DARCY FRICTION FACTOR

Detail Darcy friction factor is proposed by Lewis Ferry Moody (5 January 1880 – 21 February 1953)



Material	ε (mm)
Concrete, coarse	0.25
Concrete, new smooth	0.025
Drawn tubing	0.0025
Glass, Plastic Perspex	0.0025
Iron, cast	0.15
Sewers, old	3.0
Steel, mortar lined	0.1
Steel, rusted	0.5
Steel, structural or forged	0.025
Water mains, old	1.0

MOODY DIAGRAM



Colebrook – White Equation

Most accurate representation of Moody diagram in Turbulence region

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon}{3.7D_{\mathrm{h}}} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

Implicit form, must be solved iteratively

APPROXIMATION OF FRICTION FACTOR IN TURBULENT REGIME

Equation	Author	Year	Range
$f = .0055\left[1+\left(2\times10^4\cdot\frac{\varepsilon}{D}+\frac{10^6}{\mathrm{Re}}\right)^{\frac{1}{3}}\right]$	Moody	1947	$Re = 4000 - 5.10^8$ $\varepsilon/D = 0 - 0.01$
$f = .094\left(\frac{\varepsilon}{D}\right)^{0.225}+0.53\left(\frac{\varepsilon}{D}\right)+88\left(\frac{\varepsilon}{D}\right)^{0.44}\cdot\mathrm{Re}^{-\Psi}$ where $\Psi = 1.62\left(\frac{\varepsilon}{D}\right)^{0.134}$	Wood	1966	$Re = 4000 - 5.10^7$ $\varepsilon/D = 0.00001 - 0.04$
$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.715}+\frac{15}{\mathrm{Re}}\right)$	Eck	1973	
$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7}+\frac{5.74}{\mathrm{Re}^{0.9}}\right)$	Swamee and Jain	1976	$Re = 5000 - 10^8$ $\varepsilon/D = 0.000001 - 0.05$
$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.71}+\left(\frac{7}{\mathrm{Re}}\right)^{0.9}\right)$	Churchill	1973	Not specified
$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.715}+\left(\frac{6.943}{\mathrm{Re}}\right)^{0.9}\right)$	Jain	1976	

APPROXIMATION OF FRICTION FACTOR IN TURBULENT REGIME

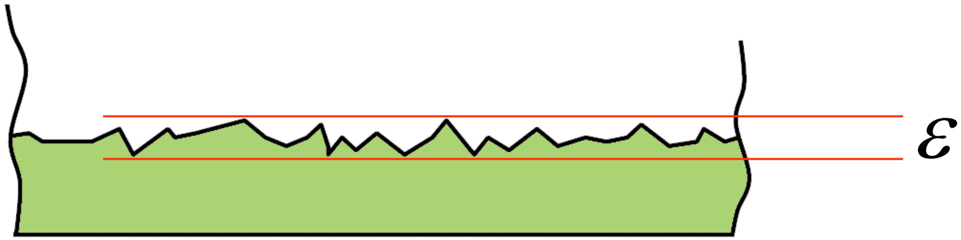
Equation	Author	Year	Range
$f = 8\left[\left(\frac{8}{\mathrm{Re}}\right)^{12} + \frac{1}{(\Theta_1 + \Theta_2)^{1.5}}\right]^{\frac{1}{12}}$ where $\Theta_1 = \left[-2.457\ln\left(\left(\frac{7}{\mathrm{Re}}\right)^{0.9} + 0.27\frac{\varepsilon}{D}\right)\right]^{16}$ $\Theta_2 = \left(\frac{37530}{\mathrm{Re}}\right)^{16}$	Churchill	1977	
$\frac{1}{\sqrt{f}} = -2\log\left[\frac{\varepsilon/D}{3.7065} - \frac{5.0452}{\mathrm{Re}}\log\left(\frac{1}{2.8257}\left(\frac{\varepsilon}{D}\right)^{1.1098} + \frac{5.8506}{\mathrm{Re}^{0.8981}}\right)\right]$	Chen	1979	$Re = 4000 - 4.10^8$
$\frac{1}{\sqrt{f}} = 1.8\log\left[\frac{\mathrm{Re}}{0.135\mathrm{Re}(\varepsilon/D) + 6.5}\right]$	Round	1980	
$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{4.518\log\left(\frac{\mathrm{Re}}{7}\right)}{\mathrm{Re}\left(1 + \frac{\mathrm{Re}^{0.52}}{29}(\varepsilon/D)^{0.7}\right)}\right)$	Barr	1981	
$\frac{1}{\sqrt{f}} = -2\log\left[\frac{\varepsilon/D}{3.7} - \frac{5.02}{\mathrm{Re}}\log\left(\frac{\varepsilon/D}{3.7} - \frac{5.02}{\mathrm{Re}}\log\left(\frac{\varepsilon/D}{3.7} + \frac{13}{\mathrm{Re}}\right)\right)\right]$ or $\frac{1}{\sqrt{f}} = -2\log\left[\frac{\varepsilon/D}{3.7} - \frac{5.02}{\mathrm{Re}}\log\left(\frac{\varepsilon/D}{3.7} + \frac{13}{\mathrm{Re}}\right)\right]$	Zigrang and Sylvester	1982	

APPROXIMATION OF FRICTION FACTOR IN TURBULENT REGIME

Equation	Author	Year	Range
$\frac{1}{\sqrt{f}} = -1.8\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\text{Re}}\right]$	Haaland[9]	1983	
$\frac{1}{\sqrt{f}} = \Psi_1 - \frac{(\Psi_2 - \Psi_1)^2}{\Psi_3 - 2\Psi_2 + \Psi_1}$ or $\frac{1}{\sqrt{f}} = 4.781 - \frac{(\Psi_1 - 4.781)^2}{\Psi_2 - 2\Psi_1 + 4.781}$ where $\Psi_1 = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{12}{\text{Re}}\right)$ $\Psi_2 = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51\Psi_1}{\text{Re}}\right)$ $\Psi_3 = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51\Psi_2}{\text{Re}}\right)$	Serghides	1984	
$A = 0.11\left(\frac{68}{Re} + \varepsilon\right)^{0.25}$ if $A \geq 0.018$ then $f = A$ and if $A < 0.018$ then $f = 0.0028 + 0.85A$	Tsal	1989	
$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{95}{\text{Re}^{0.983}} - \frac{96.82}{\text{Re}}\right)$	Manadilli	1997	$Re = 4000 - 10^8$ $\varepsilon/D = 0 - 0.05$
$\frac{1}{\sqrt{f}} = -2\log\left\{\frac{\varepsilon/D}{3.7065} - \frac{5.0272}{\text{Re}}\log\left[\frac{\varepsilon/D}{3.827} - \frac{4.657}{\text{Re}}\log\left(\left(\frac{\varepsilon/D}{7.7918}\right)^{0.9924} + \left(\frac{5.3326}{208.815 + \text{Re}}\right)^{0.9345}\right)\right]\right\}$	Monzon, Romeo, Royo	2002	

Swamee - Jain Equation

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{\varepsilon / D}{3.7} + \frac{5.74}{\mathrm{Re}^{0.9}}\right)\right]^2}$$



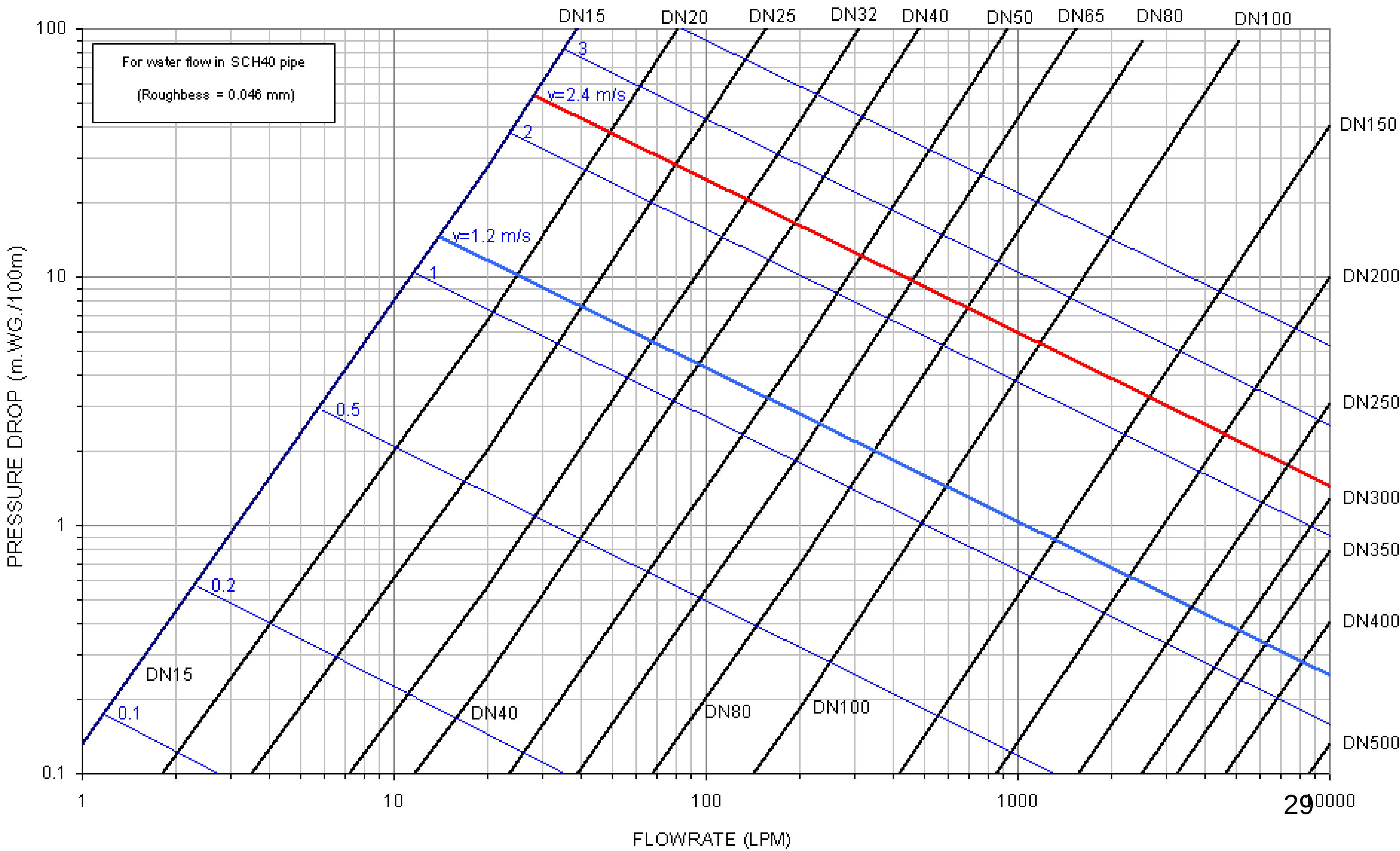
Swamee - Jain (1976)

ROUGHNESS, ε

Drawn tube	0.0015 mm
Commercial steel pipe	0.046 mm
Cast iron	0.26 mm
Concrete	0.3 – 3 mm

ROUGHNESS INCREASES WITH TIME

PRESSURE DROP CHART



HAZEN-WILLIAMS EQUATION

$$h_f = \left(\frac{151Q}{CD^{2.63}} \right)^{1.85}$$

h_f in meter per 1000 meters

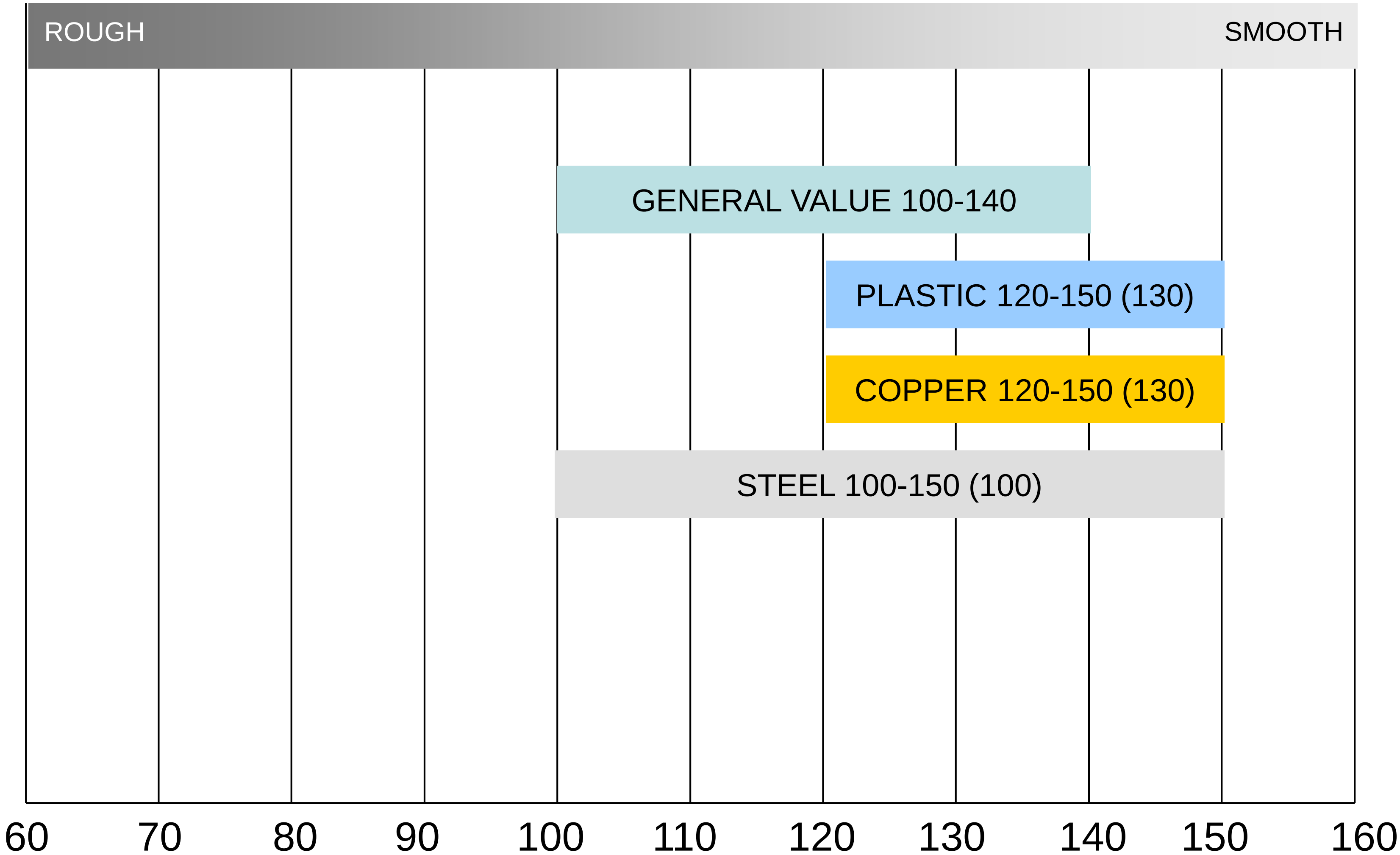
Q in cu.m./s

D in meter

C = roughness coefficient (100-140)

NOT ACCURATE BUT IN CLOSED FORM = EASY TO USE.

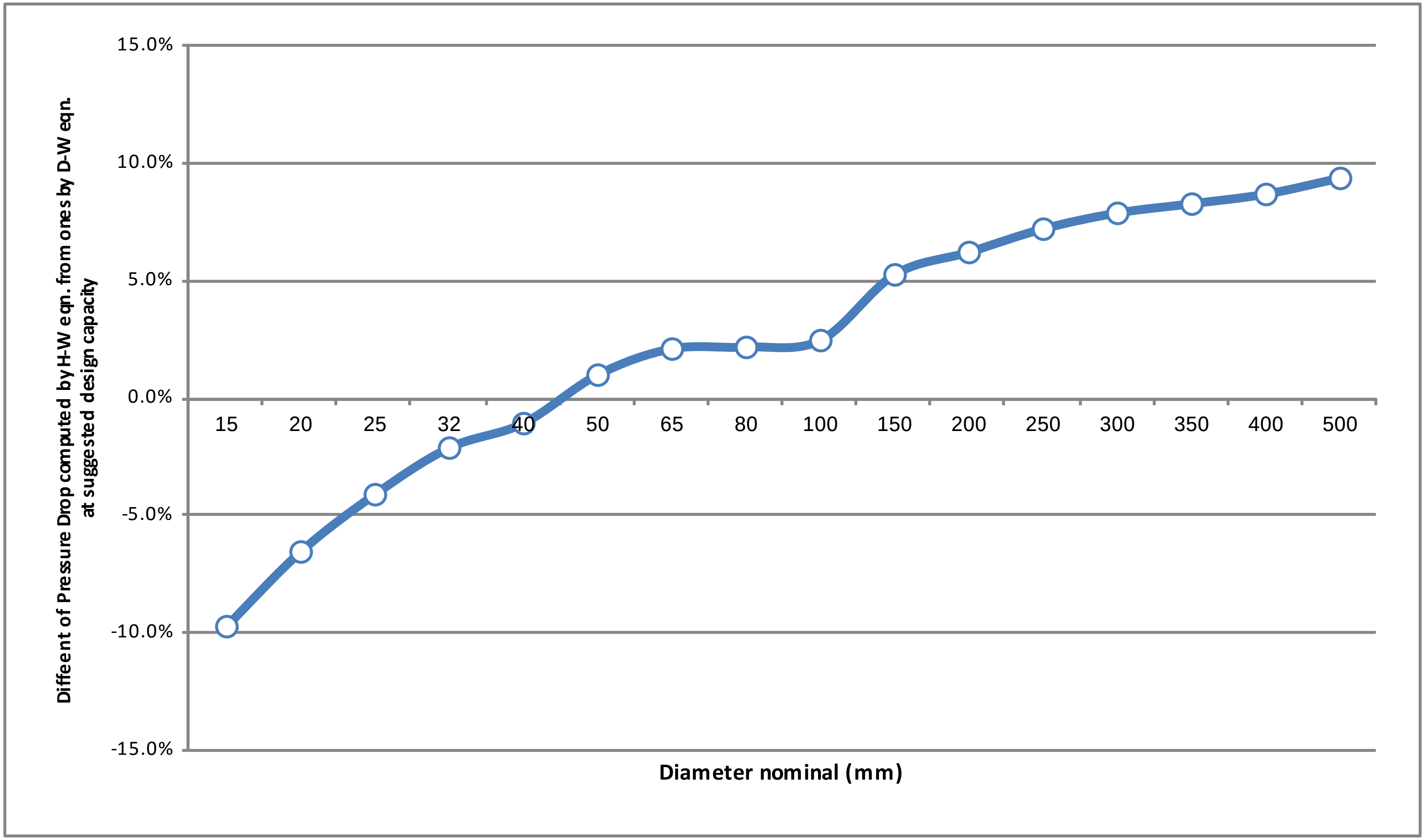
ROUGHNESS COEFFICIENT, C



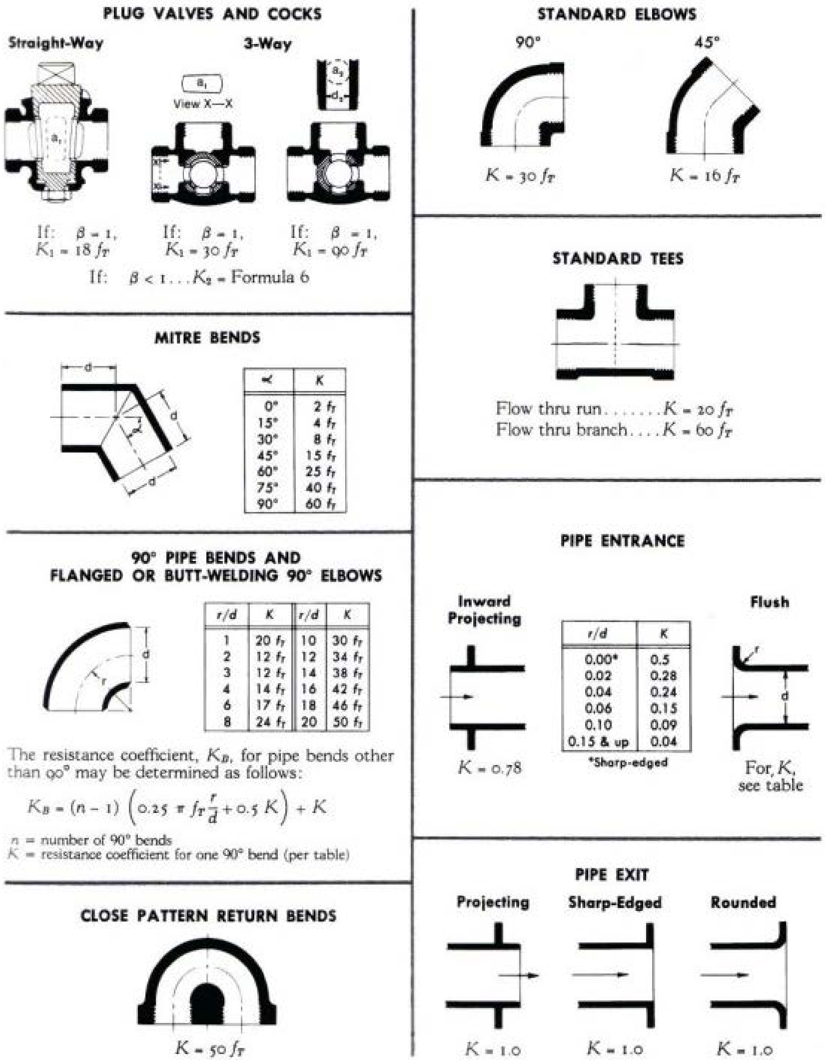
Comparison of ε and C

Material	Moody Diagram ε mm	Hazen–Williams *C*	Manning *n*[c]
Probable range of coefficients			
Plastic, FRP, and Epoxy[a]			
≤ 400 mm (16 in.)	Smooth–0.20	140–130	0.010–0.010
= 600 mm (24 in.)	Smooth–0.20	145–135	0.009–0.010
≥ 900 mm (36 in.)	Smooth–0.20	150–140	0.009–0.010
Cement mortar lining[a]			
Centrifugally spun			
≤ 400 mm (16 in.)	0.13–0.33	135–125	0.010–0.011
= 600 mm (24 in.)	0.13–0.33	140–130	0.010–0.010
≥ 900 mm (36 in.)	0.13–0.33	145–135	0.009–0.010
Trowled in place[a]			
≤ 400 mm (16 in.)	0.20–0.50	130–120	0.010–0.011
= 600 mm (24 in.)	0.20–0.50	135–125	0.010–0.011
≥ 900 mm (36 in.)	0.20–0.50	140–130	0.010–0.010
Values below taken from the general literature[b]			
Ten-State Standards [1]			
Cement mortar or plastic	0.41	120	0.011
Unlined steel or ductile iron	1.5	100	0.013
Old pipe or lining in service for 20 yr or more and nonaggressive water[b]			
Smooth glass or plastic	0.13	135	0.010
Cement mortar,			
centrifugally spun	0.19	130	0.010
troweled	0.28	125	0.011
Asbestos cement	0.28	125	0.011
Centrifugally cast CPP	0.19	130	0.010
Wood stave	0.89	110	0.012
Riveted steel	5.6	80	0.016
Concrete, formed	5.6	80	0.016
Clay, not pressurized	1.5	100	0.013
Wrought iron	1.5	100	0.013
Galvanized iron	3.0	90	0.014

Hazen vs. Darcy



LOSS IN FITTINGS



$$h = K\frac{v^2}{2g}$$

PRACTICALLY **25%-50%** IS ADDED TO THE TOTAL PIPE LENGTH TO ACCOUNT FOR LOSS IN FITTINGS AND VALVES

LOSS IN VALVES

Valve type	K
Angle	1.8–2.9
Ball	0.04
Butterfly	
25-lb Class	0.16
75-lb Class	0.27
150-lb Class	0.35
Check valves	
Ball	0.9–1.7 but see Mfr's data for specific size and flowrate.
Center-guided globe style	2.6
Double door	
8 in. or smaller	2.5
10 to 16 in.	1.2
Foot	
Hinged disc	1–1.4
Poppet	5–14
Rubber flapper	
$v < 6$ft/s	2.0
$v > 6$ ft/s	1.1
Slanting disc[d]	0.25–2.0
Swing[d]	0.6–2.2, but see Figures B-2 and B-3.
Cone	0.04
Diaphragm or pinch	0.2–0.75
Gate	
Double disc	0.1–0.2
Resilient seat	0.3
Globe	4.0–6.0
Knife gate	
Metal seat	0.2
Resilient seat	0.3
Plug	
Lubricated	0.5–1.0
Eccentric	
Rectangular (80%) opening	1.0
Full bore opening	0.5

[a] $h = Kv^2/2g$, where v is the velocity in the approach piping.

[b] For 300-mm (12-in.) valves and velocities of about 2 m/s (6 ft/s). Note that K may increase significantly for smaller valves. Consult the manufacturer.

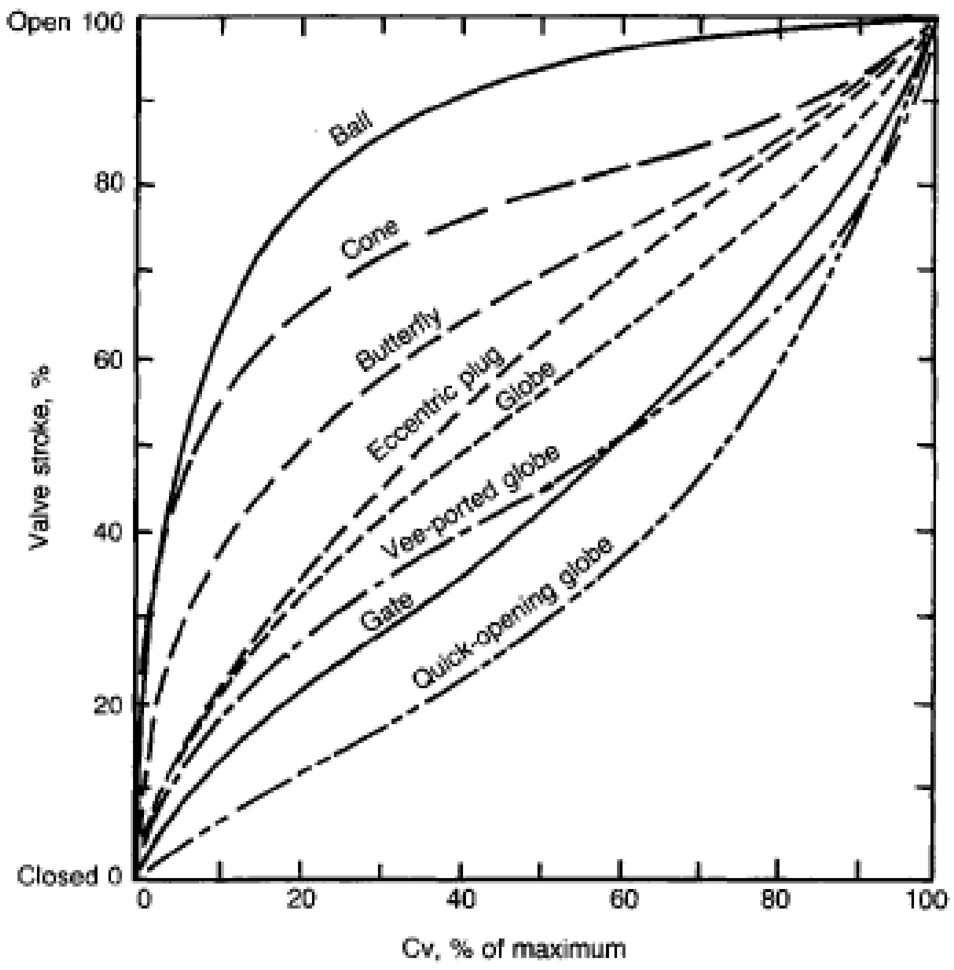
[c] Expect K to vary from –20 to +50% or more.

[d] Depending on adjustment of closure mechanism, velocity may have to exceed 4 m/s (12 ft/s) to open the valve fully. Adjustment is crucial to prevent valve slam.

$$h = K\frac{v^2}{2g}$$

PRACTICALLY **25%-50%** IS ADDED TO THE TOTAL PIPE LENGTH TO ACCOUNT FOR LOSS IN FITTINGS AND VALVES

VALVE COEFFICIENT K_v



$$K_v = Q\sqrt{\frac{S.G.}{\Delta P}}$$

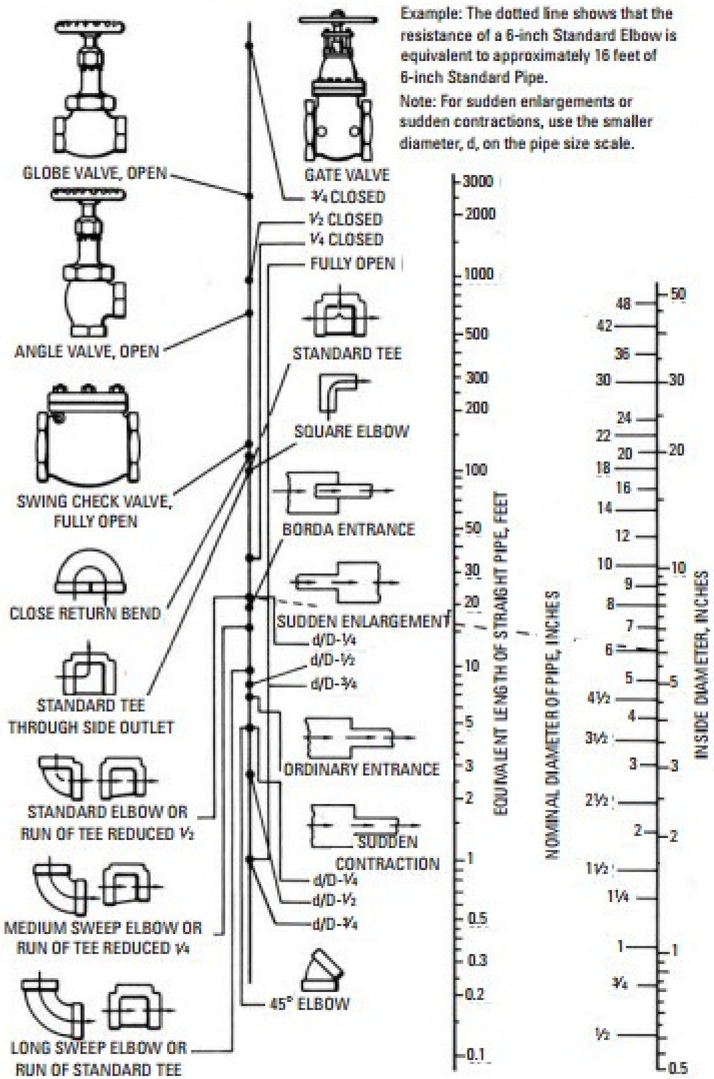
Q IN CU.M./HR
ΔP IN BAR
S.G. = SPECIFIC GRAVITY

$$K = 4.527 \times 10^7 \frac{D^4}{K_v^2}$$

Kv = 0.86 x Cv

EQUIVALENT LENGTH OF FITTINGS

Table 8-11 Diagram Showing Resistance of Valves and Fittings of the Flow of Liquids



Another way to estimate loss in fittings and valves is to use equivalent length.

http://machineryequipmentonline.com/hvac-machinery/pipes-pipe-fittings-and-piping-detailsvalves/

EQUIVALENT LENGTH – L/D

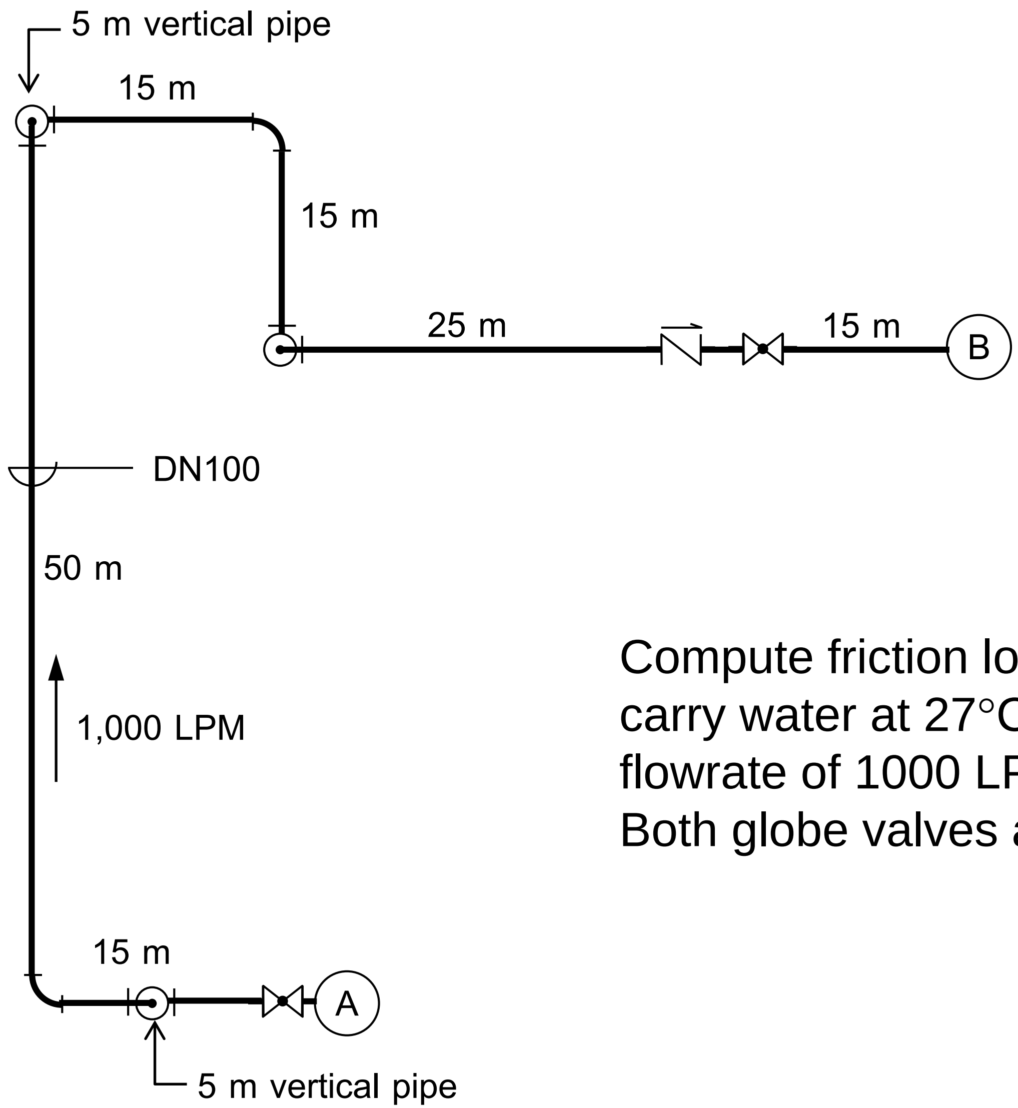
Fitting	Types	(L/D)eq
90° Elbow Curved, Threaded	Standard Radius (R/D = 1)	30
	Long Radius (R/D = 1.5)	16
90° Elbow Curved, Flanged/Welded	Standard Radius (R/D = 1)	20
	Long Radius (R/D = 2)	17
	Long Radius (R/D = 4)	14
	Long Radius (R/D = 6)	12
90° Elbow Mitered	1 weld (90°)	60
	2 welds (45°)	15
	3 welds (30°)	8
45° Elbow Curved. Threaded	Standard Radius (R/D = 1)	16
	Long Radius (R/D = 1.5)	
45° Elbow Mitered	1 weld 45°	15
	2 welds 22.5°	6
180° Bend	threaded, close-return (R/D = 1)	50
	flanged (R/D = 1)	
	all types (R/D = 1.5)	
Tee Through-branch as an Elbow	threaded (r/D = 1)	60
	threaded (r/D = 1.5)	
	flanged (r/D = 1)	20
	stub-in branch	

EQUIVALENT LENGTH – L/D

Fitting	Types	(L/D)eq
Angle valve	45°, full line size, β = 1	55
	90° full line size, β = 1	150
Globe valve	standard, β = 1	340
Plug valve	branch flow	90
	straight through	18
	three-way (flow through)	30
Gate valve	standard, β = 1	8
Ball valve	standard, β = 1	3
Diaphragm	dam type	
Swing check valve	V_{min} = 35 [ρ (lbm/ft^3)]$^{-1/2}$	100
Lift check valve	V_{min} = 40 [ρ (lbm/ft^3)]$^{-1/2}$	600
Hose Coupling	Simple, Full Bore	5

https://neutrium.net/fluid_flow/pressure-loss-from-fittings-equivalent-length-method/

EXAMPLE 4.1



Compute friction loss in a DN100 SCH40 pipe carry water at 27°C (ν=0.862X10^{-6} m^2/s) at the flowrate of 1000 LPM from A to B.
Both globe valves are fully open (K = 4)

EXAMPLE 4.1 (2)

Pipe flow area: $A = 8.213 \times 10^{-3}$ m²

Flowrate: $Q = 1{,}000$ LPM $= 0.0167$ m³/s

Velocity: $v = \dfrac{Q}{A} = \dfrac{(0.0167)}{(8.213 \times 10^{-3})} = 2.029$ m/s

$$\mathrm{Re} = \frac{vD}{\nu} = \frac{(2.029)(102.26 \times 10^{-3})}{(0.862 \times 10^{-6})} = 240{,}700$$

EXAMPLE 4.1 (3)

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{\varepsilon / D}{3.7} + \frac{5.74}{\mathrm{Re}^{0.9}}\right)\right]^2} = \frac{0.25}{\left[\log_{10}\left(\frac{0.046/102.26}{3.7} + \frac{5.74}{(240,700)^{0.9}}\right)\right]^2} = .0184$$

$$\xi = \frac{8Lf}{\pi^2 D^5 g} = \frac{8(100)(0.0184)}{\pi^2 \left(102.26\times 10^{-3}\right)^5 (9.81)} = 13,605$$ (per 100m)

$$h_f = \xi Q^2 = (13,605)(0.0167)^2 = 3.78$$ m/100m

EXAMPLE 4.1 (4)

Loss in 90 degree bend

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[a] $h = Kv^2/2g$, where v is the maximum velocity in nonprismatic fittings. Increase K by 5% for each 25-mm (1-in.) decrement in pipe smaller than 300 mm (12 in.). Expect K values to vary from –20 to +30% or more.

K = 0.25x1.4 = 0.35

$$\xi = \frac{8K}{\pi^2 D^4 g} = \frac{8 \cdot (0.35)}{\pi^2 \left(102.26 \times 10^{-3}\right)^4 \cdot (9.81)} = 264.46$$

$$h_m = \xi Q^2 = 264.46 \cdot (0.0167)^2 = 0.074$$ m/piece

EXAMPLE 4.1 (4)

Loss globe valve

$K = 4$

$$\xi = \frac{8K}{\pi^2 D^4 g} = \frac{8 \cdot (4)}{\pi^2 \left(102.26 \times 10^{-3}\right)^4 \cdot (9.81)} = 3{,}022$$

$$h_m = \xi Q^2 = 3{,}022 \cdot (0.0167)^2 = 0.846 \quad \text{m/valve}$$

Loss check valve

$K = 2$ → Half of globe valve

$$h_m = 0.423 \quad \text{m/valve}$$

EXAMPLE 4.1 (5)

Components	Size	Quantity	Pressure drop/unit	Pressure drop (m.WG.)
Major loss				
Straight pipe	DN100	150 m	3.78 m/100m	5.67
Minor loss				
Elbows	DN100	8 pcs	0.074 m/pc	0.59
Globe valves	DN100	2 pcs	0.846 m/pc	1.69
Check Valve	DN100	1 pc	0.423 m/pc	0.42
Minor loss				2.71 (48% of 5.67)
Total Pressure drop				8.38

EXAMPLE 4.1 (NOTE)

varies with flow rate (but not much)

Loss in pipe (100m) $$h_f = 13{,}605Q^2$$

Loss in 90 degree bend (per elbow) $$h_m = 264.46Q^2$$

Loss in globe valve (per valve) $$h_m = 3{,}022Q^2$$

Loss in check valve (per valve) $$h_m = 1{,}511Q^2$$

Loss in the system

$$h_l = (150/100) \times 13{,}605 + 8 \times 264.46 + 2 \times 3{,}022 + 1{,}511Q^2$$

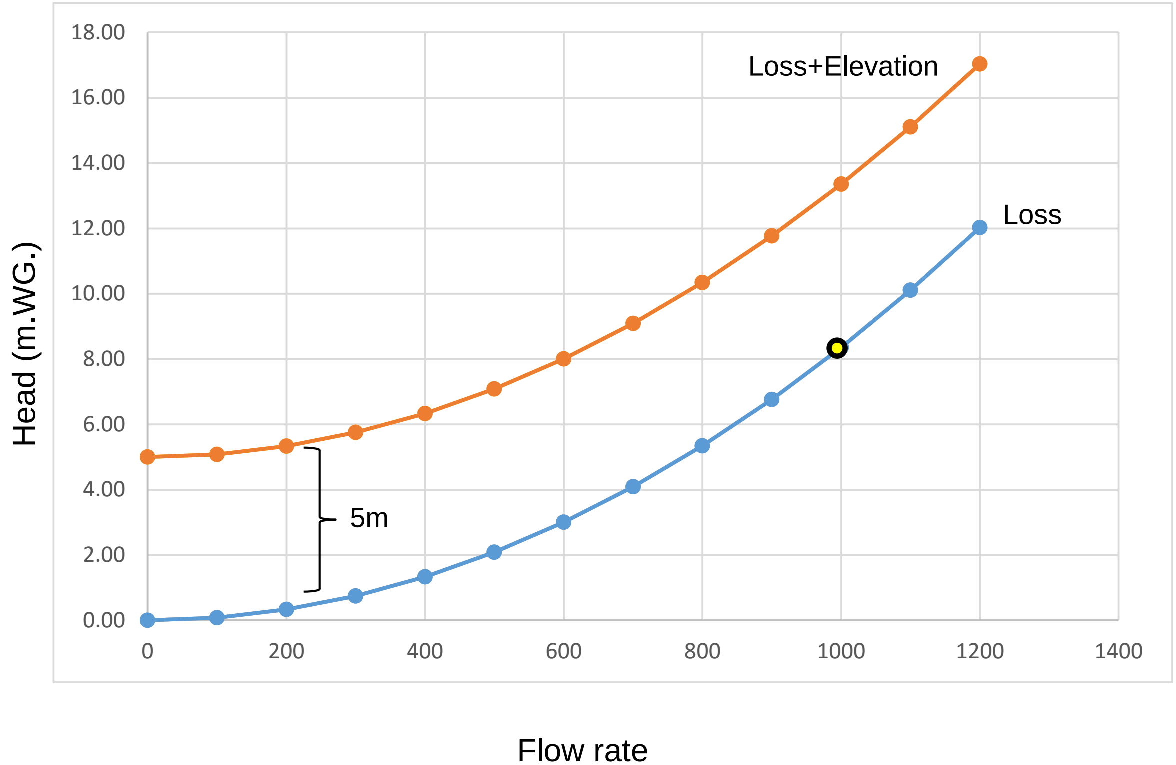
$$h_l = 30{,}078Q^2$$

EXAMPLE 4.1 (NOTE)

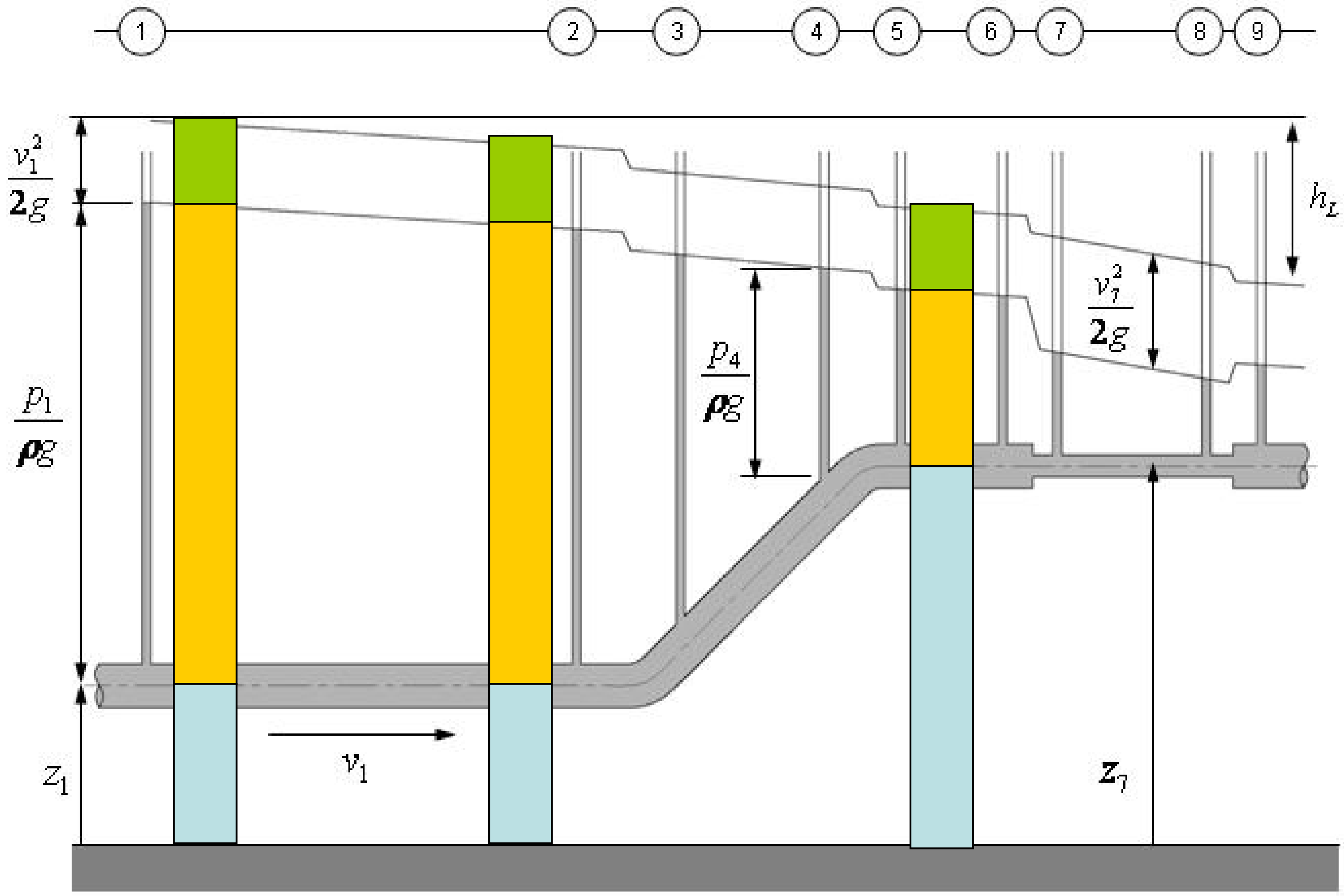
$$h_l = 30{,}078Q^2$$

Point B is 5m higher than point A

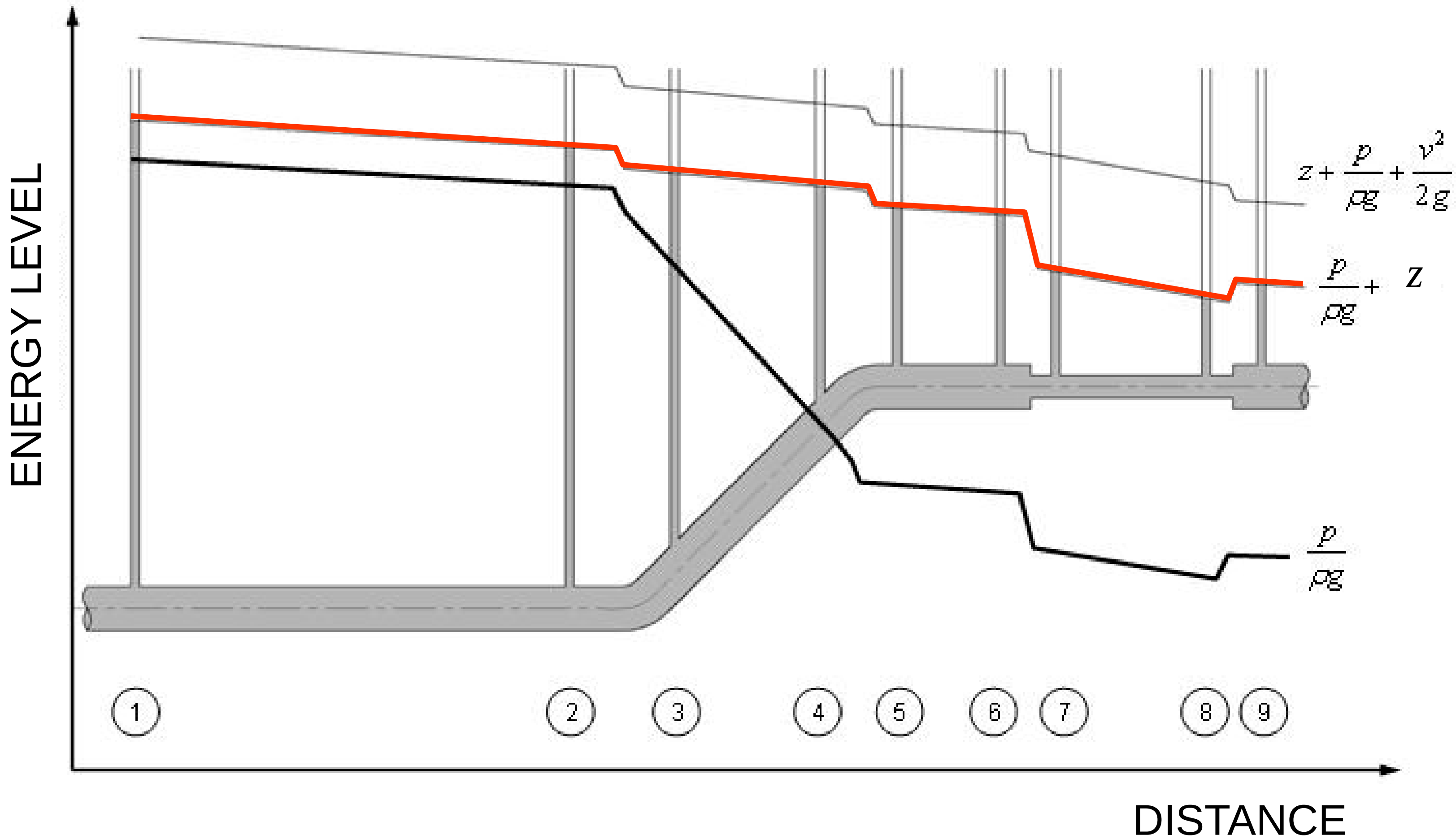
Flow LPM	Loss (m.WG.)	System head (m.WG.)
0	0.00	5.00
100	0.08	5.08
200	0.33	5.33
300	0.75	5.75
400	1.34	6.34
500	2.09	7.09
600	3.01	8.01
700	4.09	9.09
800	5.35	10.35
900	6.77	11.77
1,000	8.36	13.36
1,100	10.11	15.11
1,200	12.03	17.03



ENERGY GRADE LINE

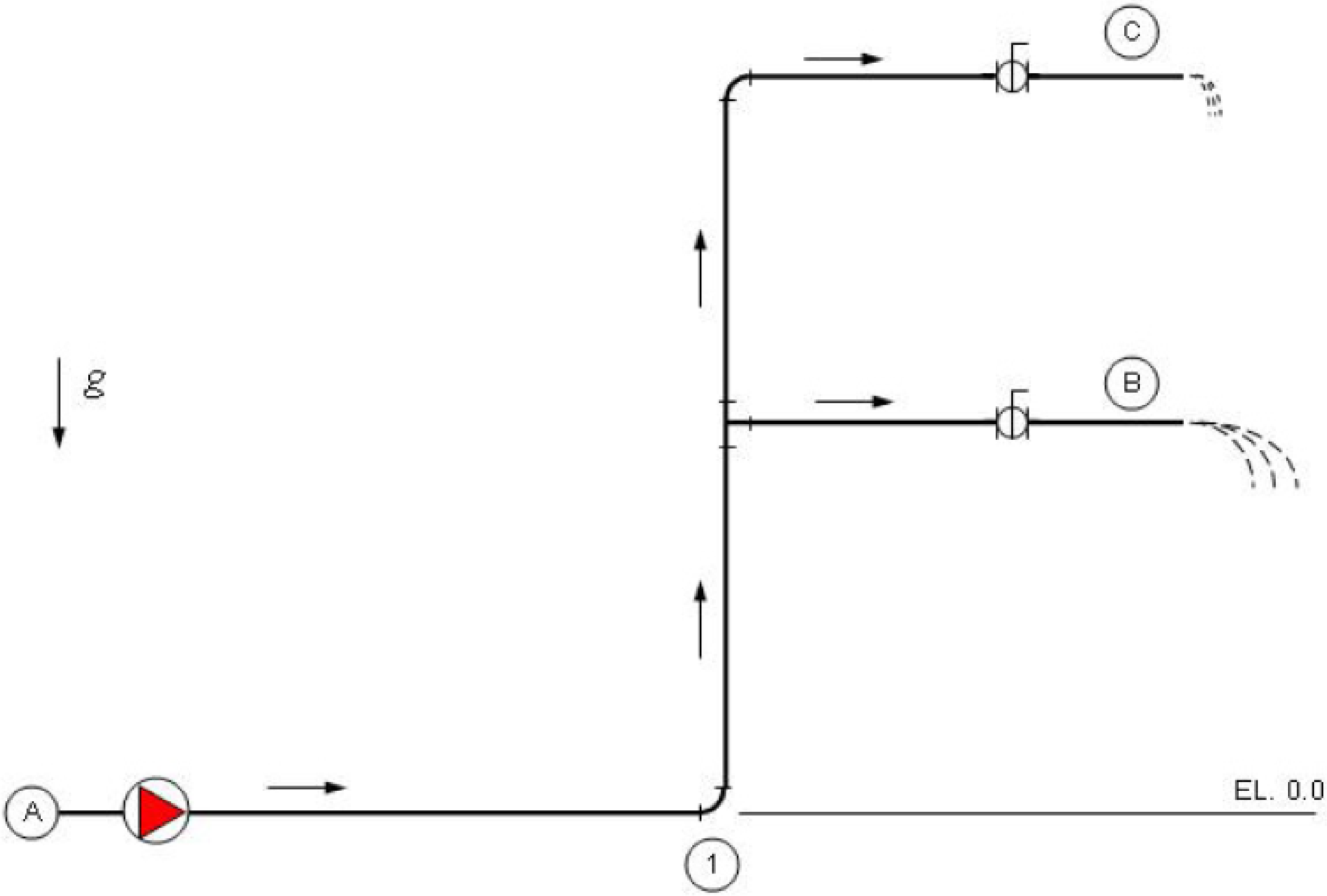


HYDRAULIC GRADE LINE

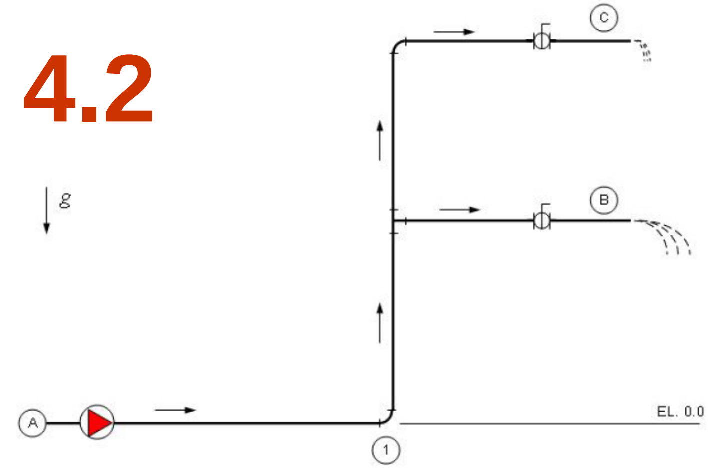


EXAMPLE 4.2

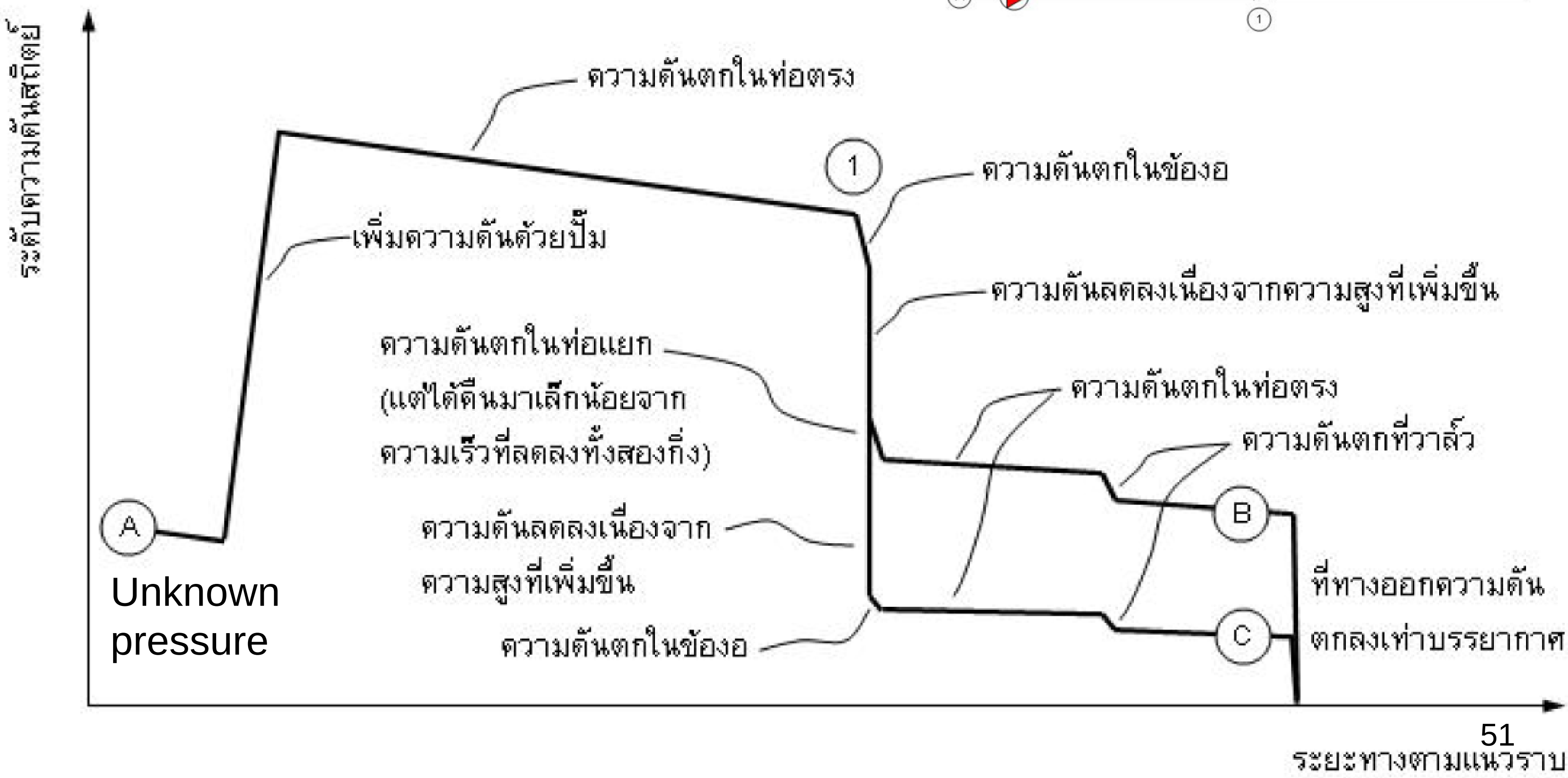
Draw static pressure line from point A to points B and C.



EXAMPLE 4.2



C
B
g
A
1
EL. 0.0



ระดับความดันสถิตย์
ความดันตกในท่อตรง
1
ความดันตกในข้องอ
เพิ่มความดันด้วยปั๊ม
ความดันลดลงเนื่องจากความสูงที่เพิ่มขึ้น
ความดันตกในท่อแยก
(แต่ได้คืนมาเล็กน้อยจาก
ความเร็วที่ลดลงทั้งสองกิ่ง)
ความดันตกในท่อตรง
ความดันตกที่วาล์ว
A
B
ความดันลดลงเนื่องจาก
ความสูงที่เพิ่มขึ้น
Unknown
pressure
ที่ทางออกความดัน
ตกลงเท่าบรรยากาศ
C
ความดันตกในข้องอ
ระยะทางตามแนวราบ

EXCEL SPREADSHEET

Darcy-Weisbach Equation

Roughness, e — 0.046 mm

Density — 996 kg/cu.m. (Water at 30C)

Kinematic viscosity — 8.00E-07 m2/s (Water at 30C)

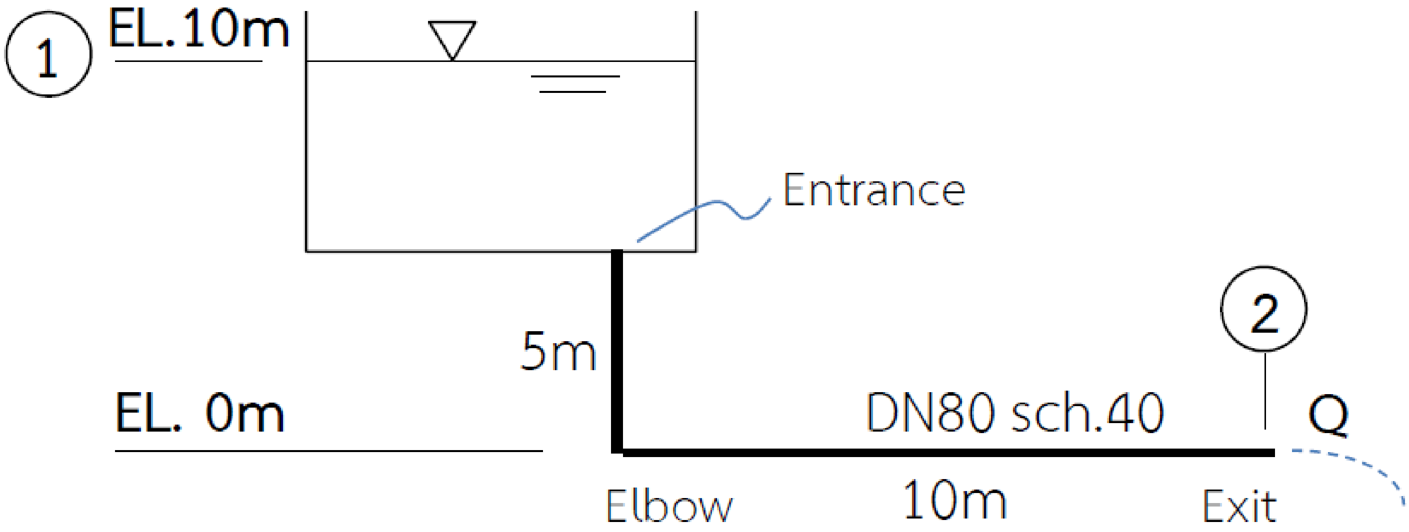
Flow LPM	DN (mm)	Length (m)	Velocity (m/s)	P-drop (m/100m)	(m)	(Bars)
8	15	100	0.680	5.03	5.03	0.49
20	20	100	0.968	6.72	6.72	0.66
35	25	100	1.046	5.70	5.70	0.56
72	32	100	1.280	6.00	6.00	0.59
114	40	100	1.446	6.11	6.11	0.60
190	50	100	1.462	4.56	4.56	0.45
300	65	100	1.578	4.17	4.17	0.41
570	80	100	1.991	5.04	5.04	0.49
1140	100	100	2.312	4.81	4.81	0.47
2560	150	100	2.288	2.86	2.86	0.28
4650	200	100	2.400	2.25	2.25	0.22
7320	250	100	2.397	1.70	1.70	0.17
10400	300	100	2.399	1.38	1.38	0.14
12500	350	100	2.385	1.22	1.22	0.12
16400	400	100	2.397	1.05	1.05	0.10
25800	500	100	2.396	0.80	0.80	0.08

Calculation

FLOW (CU.m./s)	Dia. (m)	Velocity (m/s)	e/D	Re	f	P-drop (m/100m)
0.000	0.016	0.680	0.003	13,426	0.034	5.028
0.000	0.021	0.968	0.002	25,337	0.029	6.724
0.001	0.027	1.046	0.002	34,830	0.027	5.701
0.001	0.035	1.280	0.001	55,265	0.025	5.997
0.002	0.041	1.446	0.001	73,916	0.023	6.109
0.003	0.053	1.462	0.001	95,956	0.022	4.565
0.005	0.064	1.578	0.001	125,268	0.021	4.166
0.010	0.078	1.991	0.001	193,946	0.019	5.041
0.019	0.102	2.312	0.000	295,591	0.018	4.812
0.043	0.154	2.288	0.000	440,625	0.017	2.860
0.078	0.203	2.400	0.000	608,213	0.016	2.249
0.122	0.255	2.397	0.000	762,612	0.015	1.705
0.173	0.303	2.399	0.000	909,415	0.014	1.384
0.208	0.333	2.385	0.000	994,118	0.014	1.221
0.273	0.381	2.397	0.000	1,141,335	0.014	1.050
0.430	0.478	2.396	0.000	1,431,525	0.013	0.802

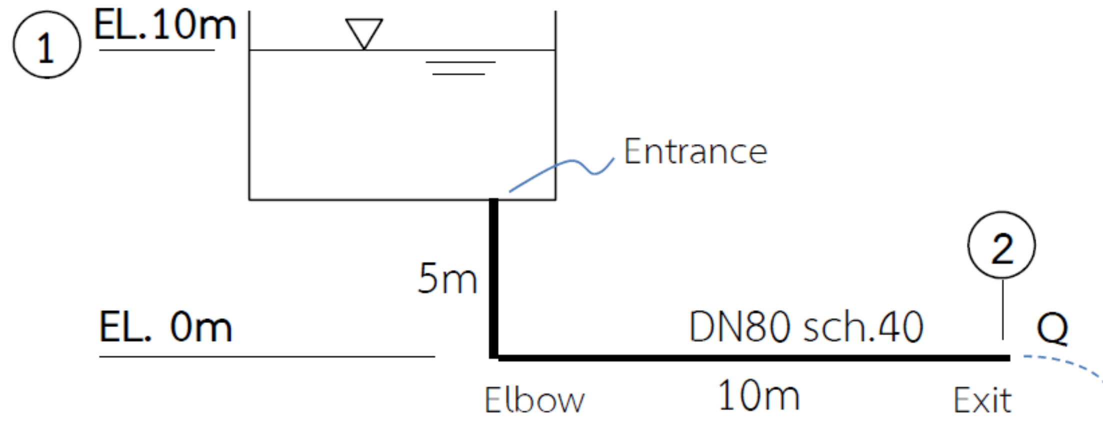
EXAMPLE 4.3

Estimate flowrate Q



EXAMPLE 4.3

Method 1 – Neglect loss



$$z_1 = \frac{V_2^2}{2g} \quad \text{หรือ} \quad v_2 = \sqrt{2gz_1} = \sqrt{2 \times 9.81 \times 10} = 14 \text{ m/s}$$

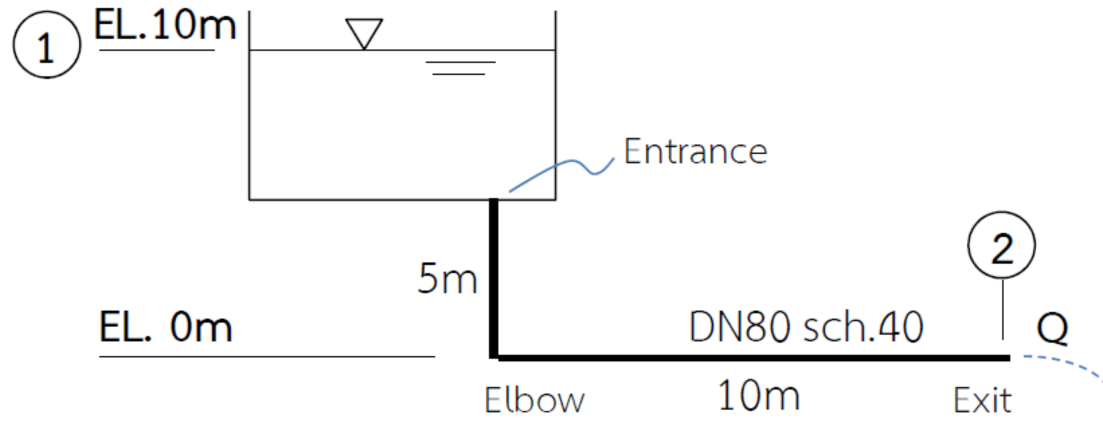
$$A = \frac{\pi D^2}{4} = \frac{\pi \left(77.93 \times 10^{-3}\right)^2}{4} = 4.77 \times 10^{-3} \text{ m}^2$$

$$Q = v_2 A = 14 \times 4.77 \times 10^{-3} = 0.0668 \text{ m}^3/\text{s} \text{ หรือ } 4{,}007 \text{ lpm}$$

EXAMPLE 4.3

Method 2 – Include loss

$$z_1 = \frac{V_2^2}{2g} + h_L$$



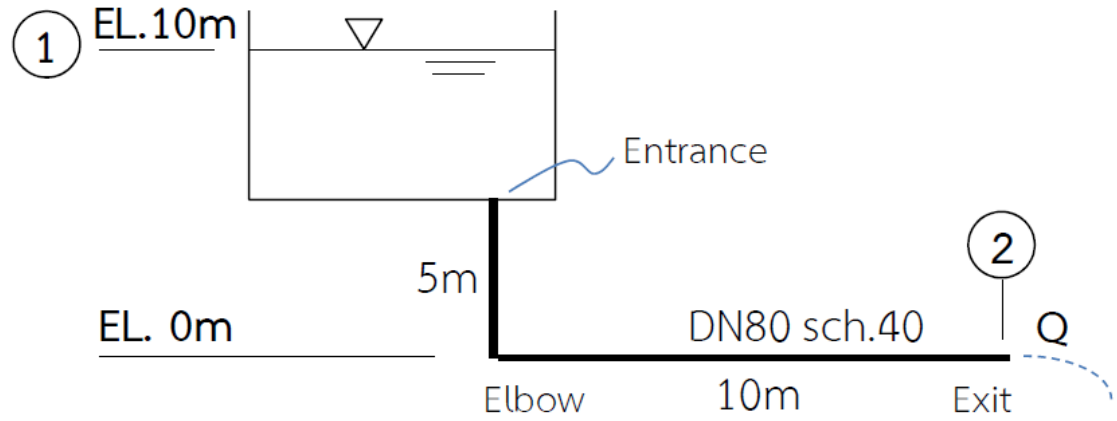
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Flow	DN	Length	Velocity	P-drop/ 100m		P-drop Total	
LPM	(mm)	(m)	(m/s)	(m.WG./100r	(Bars/100m)	(m.Fluid)	(Bars)
1000	80	19.5	3.493	14.85	1.4570219	2.90	0.28

(1)	(2)	(3)	(4)	(7)	(9)	(10)
Flow **LPM**	DN (mm)	Length (m)	v (m/s)	hL (m.WG.)	v^2/ 2g	v^2 /2g + hL
1000	80	19.5	3.493	2.91	0.62	3.53

EXAMPLE 4.3

Method 2 – Include loss

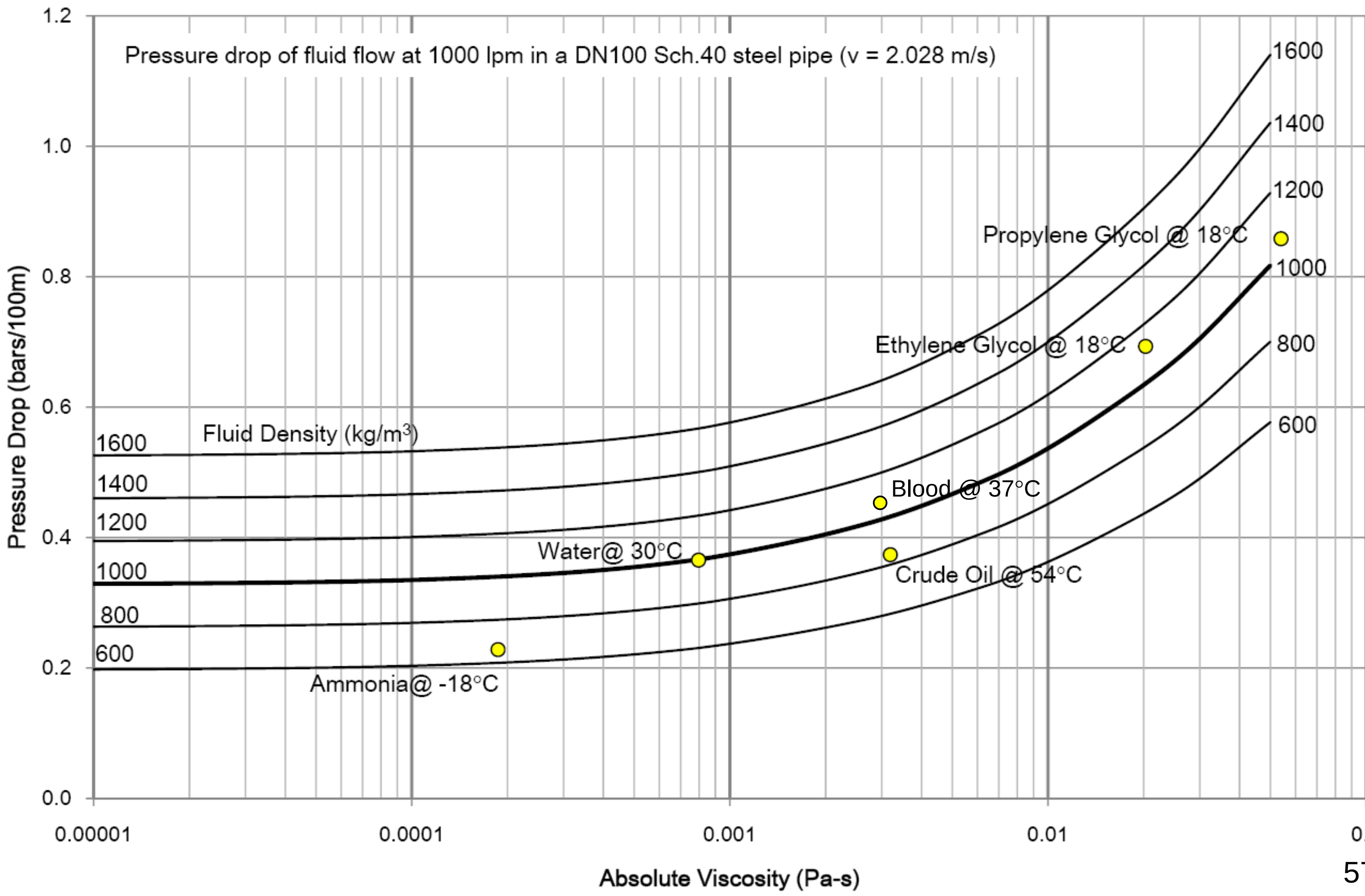
$$z_1 = \frac{V_2^2}{2g} + h_L$$



(1) Flow LPM	(2) DN (mm)	(3) Length (m)	(4) v (m/s)	(7) hL (m.WG.)	(9) v^2/ 2g	(10) v^2 /2g + hL
1000	80	19.5	3.493	2.91	0.62	3.53

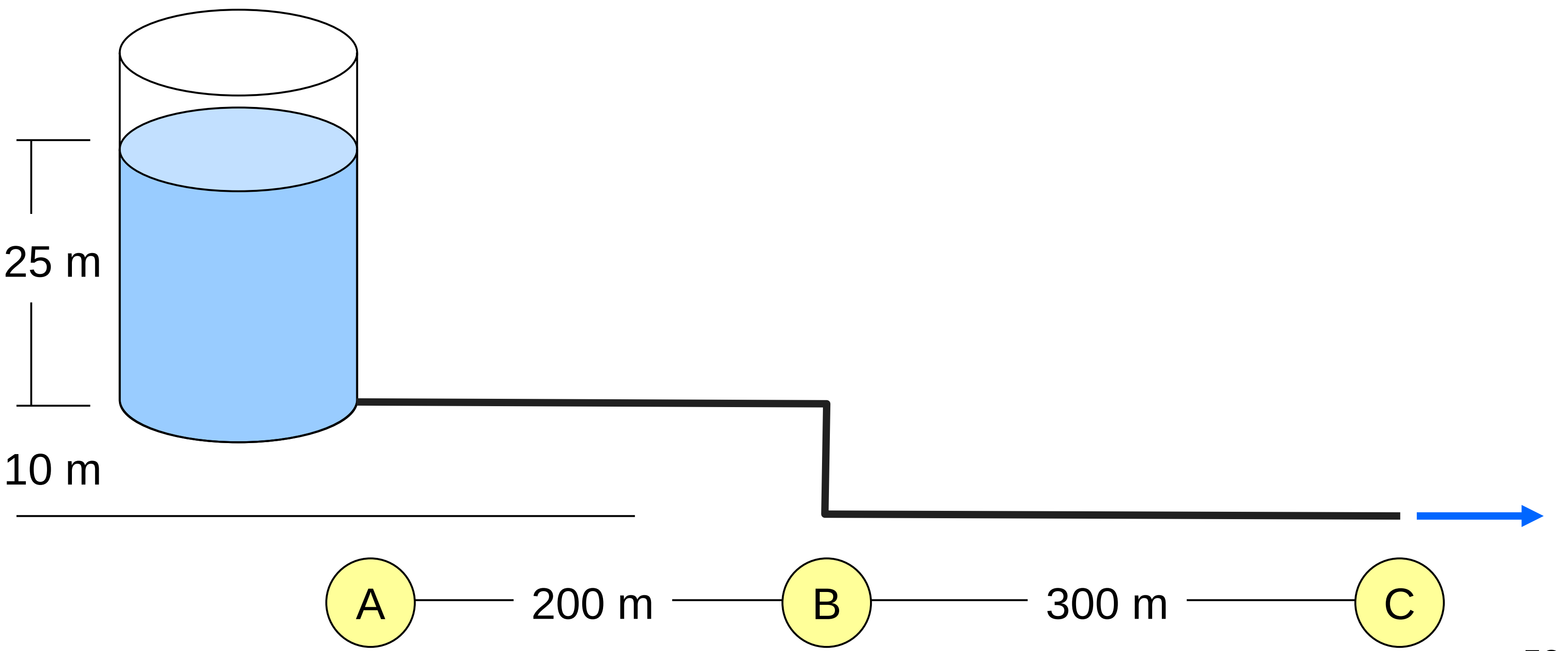
(1) Flow LPM	(2) DN (mm)	(3) Length (m)	(4) v (m/s)	(7) hL (m.WG.)	(9) v^2/ 2g	(10) v^2 /2g + hL
1701	80	19.5	5.942	8.20	1.80	10.00

EFFECT OF VISCOSITY AND DENSITY



HOMEWORK 4

1. DETERMINE THE SUITABLE DIAMETER OF A SMOOTH PIPE TO TRANFER XX0 LPM OF WATER FROM POINT *A* TO POINT *C*. THE MINIMUM PRESSURE REQUIRED AT *C* IS 1 BARg.
2. ASSUME THAT THE FLOW RATE OF XX0 LPM IS ACHIEVED IN THIS SYSTEM, ESTIMATE THE VELOCITY HEAD IN PERCENTAGE OF THE TOTAL HEAD?
3. SKETCH ENERGY LINE, HYDRAULIC GRADE LINE AND STATIC PRESSURE LINE.



XX is the last two digits of your student ID. If it is 00 then use the last three digits instead