INCOMPRESSIBLE FLOW CALCULATOR

Simon Learman

Blackmonk Engineering Ltd
www.blackmonk.co.uk

Contents

Introduction

This document describes the basis and operation of the Blackmonk Engineering Incompressible Flow Calculator.

The calculation methodology is based on that described in Crane Technical Paper 410M “The Flow of Fluids Through Valves, Fittings and Pipes”.

The calculator determines the pressure drop for incompressible flow through a line given the required fluid flow rate and details of the piping system. The system can be comprised of up to 3 pipes in series of differing diameters.

The calculator determines the static and frictional pressure drop based on the Darcy-Weisbach formula.

Calculation Inputs

The following parameters are user specified inputs to the calculation:

Line Details

Input	Description	Units
Line number	Optional user specified line number	N/A
Source	Optional user specified source of line	N/A
Destination	Optional user specified destination of line	N/A

Fluid Properties

Input	Description	Units
Fluid	Optional user specified name of fluid	N/A
Phase	Optional user specified phase of fluid	N/A
Flow rate	Mandatory user specified mass flow rate	kg/hr
Density	Mandatory user specified fluid density	kg/m^3
Viscosity	Mandatory user specified fluid viscosity	cP

Elevations

Input	Description	Units
Line inlet centreline elevation	Mandatory user specified line inlet centre line elevation above the datum	m
Line outlet centreline elevation	Mandatory user specified line outlet centre line elevation above the datum	m

Pipelines

Input	Description	Units
Pipe nominal diameter	Mandatory user specified pipe nominal bore (nominal diameter)	inch
Pipe schedule	Mandatory user specified pipe schedule. Selected from a drop down list of valid values for the specified pipe nominal bore	N/A
Pipe length	Mandatory user specified pipe length	m
Absolute roughness	Mandatory user specified absolute roughness of the inside of the pipe	mm

Fittings

Input	Description	Units
90° LR bends	Mandatory user specified quantity of 90° long radius bends (can be zero)	N/A
90° Std elbows	Mandatory user specified quantity of 90° standard radius elbows (can be zero)	N/A
45° LR bends	Mandatory user specified quantity of 45° long radius bends (can be zero)	N/A
45° Std elbows	Mandatory user specified quantity of 45° standard radius elbows (can be zero)	N/A
Straight tees (flow thro' run)	Mandatory user specified quantity of straight tees with the fluid flow through the tee (can be zero)	N/A
Straight tees (flow thro' branch)	Mandatory user specified quantity of straight tees with the fluid flow through the branch of the tee (can be zero)	N/A
Pipe entrances	Mandatory user specified quantity of pipe entrances (can be zero)	N/A
Pipe exits	Mandatory user specified quantity of pipe exits (can be zero)	N/A
Pipe contractions	Mandatory user specified quantity of pipe contractions (can be zero)	N/A
Pipe expansions	Mandatory user specified quantity of pipe expansions (can be zero)	N/A
Gate valves	Mandatory user specified quantity of gate valves (can be zero)	N/A
Globe valves	Mandatory user specified quantity of globe valves (can be zero)	N/A
Swing check valves	Mandatory user specified quantity of swing check valves (can be zero)	N/A
Lift check valves	Mandatory user specified quantity of lift check valves (can be zero)	N/A
Tilting disc check valves	Mandatory user specified quantity of tilting check valves (can be zero)	N/A
Stop check valves	Mandatory user specified quantity of stop check valves (can be zero)	N/A
Poppet foot valves (with strainers)	Mandatory user specified quantity of poppet foot valves (can be zero)	N/A
Hinged disc foot valves (with strainers)	Mandatory user specified quantity of hinged disc foot valves with strainers (can be zero)	N/A
Ball valves	Mandatory user specified quantity of ball	N/A

	valves (can be zero)	
Butterfly valves	Mandatory user specified quantity of butterfly valves (can be zero)	N/A
Plug valves	Mandatory user specified quantity of plug valves (can be zero)	N/A
Miscellaneous losses	Mandatory user specified quantity of miscellaneous velocity head losses (can be zero)	N/A
Fittings factor	Mandatory user specified design factor to be applied to the total number of fittings velocity head losses	N/A

Calculation Outputs

The following parameters are calculated by the software and displayed to the user:

Output	Description	Units
Pipe internal diameter	The pipe internal diameter determined from the selected pipe nominal diameter and schedule	mm
Volumetric flow rate	Volumetric flow rate of fluid calculated from the specified mass flow rate and the fluid density	m^3/hr
Relative roughness	Ratio of absolute pipe roughness to pipe internal diameter	N/A
Flow area	Cross sectional area of the inside of the pipe	m^2
Velocity	Fluid velocity through the pipe based on the flow area	m/s^2
Reynolds No.	Fluid Reynolds number based on the pipe internal diameter	N/A
Flow regime	Laminar, transition or turbulent based on the Reynolds number	N/A
Friction factor	Darcy friction factor	N/A
Pipe velocity head loss	Velocity head loss resistance coefficient for the pipe excluding fittings	N/A
Fittings total velocity head loss	Total velocity head loss resistance coefficient for the pipe fittings including the fittings factor	N/A
Frictional pressure loss	Frictional pressure drop through pipe	bar
Frictional head loss	Frictional head loss through pipe	m
Static pressure loss	Static pressure drop through line from inlet to outlet	bar
Static head loss	Static head loss through line from inlet to outlet	m
Total pressure loss	Total pressure loss through the system including static and frictional pressure losses	bar
Total head loss	Total head loss through the system including static and frictional pressure losses	m

Incompressible Flow in a Pipe

Incompressible flow applies to the flow of liquids in a pipe. It can also apply to the flow of gases and vapours under the following circumstances:

1. If the calculated pressure drop between the pipe inlet and outlet is less than 10% of the inlet pressure, it is reasonable to use the Darcy-Weisbach formula for incompressible flow using the fluid density at either the pipe inlet or outlet.
2. If the calculated pressure drop between the pipe inlet and pipe outlet is between 10% and 40% of the inlet pressure, the Darcy-Weisbach formula for incompressible flow using a fluid density based on the average of the pipe inlet and outlet conditions will give reasonable accuracy.

Static Head Loss

The static head loss in a system is the loss in pressure head due to differences in elevation between the system inlet and system outlet. Static head loss is calculated using the following:

$$H_{static\_head\_loss} = z_{out} - z_{in} \qquad \textbf{Equation 1}$$

Frictional Head Loss

The total frictional head loss in a system is the sum of the frictional head loss in the pipe and the frictional head loss in the fittings.

$$H_{friction\_head\_total} = H_{friction\_head\_pipe} + H_{friction\_head\_fittings} \qquad \textbf{Equation 2}$$

Frictional head loss through a pipe is calculated using the Darcy-Weisbach formula (Ref: Crane Technical Paper 410M, Page 1-6):

$$H_{friction\_head\_pipe} = f \frac{L}{d} \frac{u^2}{2g} \qquad \textbf{Equation 3}$$

This relationship can also be expressed in terms of velocity head loss resistance coefficient:

$$H_{friction\_head\_pipe} = K_{pipe} \frac{u^2}{2g} \qquad \textbf{Equation 4}$$

Where

$$K_{pipe} = f\frac{L}{d}$$ **Equation 5**

Pipe Friction Factor

For laminar flow (Re<2000) the friction factor is given by (Ref: Crane Technical Paper 410M):

$$f = \frac{64}{\mathrm{Re}}$$ **Equation 6**

For turbulent flow (Re>4000) the friction factor is calculated using the Churchill equation (Ref: Perry's 7th Ed, Page 6-11):

$$f = 4\left[-4\log\left[\frac{0.27\varepsilon}{d} + \left(\frac{7}{\mathrm{Re}}\right)^{0.9}\right]\right]^{-2}$$ **Equation 7**

In the transition zone between 2000 < Re < 4000 the friction factor is indeterminate and has lower limits based on laminar flow conditions and upper limits based on turbulent flow conditions. To produce a conservative value for the calculated friction factor, the turbulent flow friction factor equation is used throughout the transition zone in this calculation.

Fittings Frictional Head Loss

Frictional head loss through pipe fittings is calculated using the "resistance coefficient" version of the Darcy-Weisbach equation (Ref: Crane Technical Paper 410M, Page 2-8):

$$H_{friction\_head\_fittings} = K_{fittings}\frac{u^2}{2g}$$ **Equation 8**

The resistance coefficient of the various pipe fittings used in the calculator are based on data from Crane Technical Paper 410M. In general the resistance coefficient for each type of fitting is dependent on the nominal size of the pipe fitting.

In these cases, the resistance coefficient for each type and size of fitting is calculated from the following equation:

$$K_{fitting} = C \times f_T$$ **Equation 9**

Where C is a constant representing the equivalent length:diameter of the particular fitting and f_T is the friction factor for the appropriate size of the fitting.

Table 1: Fitting Friction Factors

Nominal Pipe Size (in)	Fitting Friction Factor f_T
0.125	0.036
0.25	0.031
0.375	0.028
0.5	0.027
0.75	0.025
1	0.023
1.25	0.022
1.5	0.021
2	0.019
2.5	0.018
3	0.018
4	0.017
5	0.016
6	0.015
8	0.014
10	0.014
12	0.013
14	0.013
16	0.013
18	0.012
20	0.012
22	0.012
24	0.012

Table 2: Equivalent Length:Diameter Constants for Various Fittings

Fitting	C	K
90° LR bends	14	-
90° Std elbows	30	-
45° LR bends	10	-
45° Std elbows	16	-
Straight tees (flow thro' run)	20	-
Straight tees (flow thro' branch)	60	-
Pipe entrances	-	0.5
Pipe exits	-	1
Pipe contractions	-	0.5
Pipe expansions	-	1
Gate valves	8	-
Globe valves	340	-
Swing check valves	50	-
Lift check valves	600	-
Tilting disc check valves	40	-
Stop check valves	400	-
Poppet foot valves (with strainers)	420	-

Hinged disc foot valves (with strainers)	75	-
Ball valves	3	-
Butterfly valves	45	-
Plug valves	18	-

Sometimes, the exact type and quantities of fittings in a line are undefined. In this case the length of the line is often multiplied by a “fittings factor” to provide some allowance for the head loss of the undefined fittings.

The calculator provides the facility to apply a “fittings factor” to each pipe length. By default, the fittings factor is 1. The “fittings factor” has the effect of modifying the pipe frictional head loss as follows:

$$K'_{pipe} = xK_{pipe}$$ **Equation 10**

Total Frictional Head Loss

The total frictional head loss of the pipe and fittings combined is given by the following equation:

$$K_{total} = K'_{pipe} + K_{fittings}$$ **Equation 11**

The total frictional head loss can then be calculated by:

$$H_{friction\_total} = K_{total} \frac{u^2}{2g}$$ **Equation 12**

Total Head Loss

The total head loss is the sum of the total static and frictional head losses in the system.

$$H_{total\_head\_loss} = H_{friction\_total} + H_{static\_head\_loss}$$ **Equation 13**

Calculation of Fluid Velocity

Fluid velocity is calculated using the user specified mass flow rate, the fluid density and the internal pipe diameter defined by the selected nominal pipe size and schedule.

The flow area is given by:

$$A = \frac{\pi d^2}{4}$$ **Equation 14**

The volumetric flow rate is determined using:

$$Q = \frac{m}{\rho}$$ **Equation 15**

The fluid velocity is then determined by:

$$u = \frac{Q}{A}$$ **Equation 16**

Pipe Relative Roughness

The pipe relative roughness is the ratio of the absolute roughness of the inside of the pipe to the pipe inside diameter.

$$\text{Relative roughness} = \frac{\varepsilon}{d}$$ **Equation 17**

Reynolds Number

Reynolds number is determined using the relationship:

$$\mathrm{Re} = \frac{\rho u d}{\mu}$$ **Equation 18**

Flow Regime

The calculator classifies the flow regime as laminar, transition or turbulent based on the Reynolds number.

Table 3: Flow Regime Classification

Reynolds Number	Flow Regime
Re < 2000	Laminar
2000 < Re < 4000	Transition
Re > 4000	Turbulent

Pressure Drop and Head Loss

Pressure drop and head loss are related to each other via the following equation:

$\Delta P = H\rho g$ **Equation 19**

Calculation of Incompressible Pressure Drop

The incompressible pressure drop is determined from the specified fluid properties, inlet conditions, pipe details and fittings details.

The calculation routine is described in the following steps:

1. Calculate the volumetric flow rate using Equation 15
2. Calculate pipe relative roughness for each specified pipe using Equation 17
3. Calculate flow area for each specified pipe using Equation 14
4. Calculate the fluid velocity for each specified pipe using Equation 16
5. Calculate Reynolds number for each specified pipe using Equation 18
6. Determine flow regime for each specified pipe using Table 3
7. Calculate pipe friction factor for each specified pipe using Equation 6 for laminar flow and Equation 7 for transition and turbulent flow
8. Calculate pipe velocity head loss for each specified pipe using Equation 5
9. Calculate fittings velocity head loss for each specified pipe using Equation 9, Table 1 and Table 2 for each fitting
10. Calculate total velocity head loss for the pipe and fittings for each specified pipe using Equation 11
11. Calculate the total frictional pressure and head loss for each specified pipe using Equation 12 and Equation 19
12. Calculate the total system static pressure and head loss using Equation 1 and Equation 19
13. Calculate the total system pressure and head loss using Equation 13 and Equation 19

Nomenclature

m = mass flow rate of fluid through pipe (kg.s^{-1})

ρ = Density of fluid (kg.m^{-3})

μ = Viscosity of fluid (Pa.s)

z_{in} = Elevation of centreline of line inlet (m)

z_{out} = Elevation of centreline of line outlet (m)

g = Acceleration due to gravity (m.s^{-2})

f = Darcy friction factor (dimensionless)

f_T = Fitting friction factor (dimensionless)

L = Length of pipe (m)

d = Inside diameter of pipe (m)

u = Fluid velocity (m.s^{-1})

Re = Reynolds number (dimensionless)

ε = Absolute roughness of pipe inside wall (m)

K_{pipe} = Resistance coefficient of pipe (dimensionless)

K'_{pipe} = Resistance coefficient of pipe incorporating "fittings factor" (dimensionless)

$K_{fittings}$ = Resistance coefficient of pipe fittings (dimensionless)

$K_{fitting}$ = Resistance coefficient of a particular pipe fitting (dimensionless)

K_{total} = Total resistance coefficient of pipe and pipe fittings (dimensionless)

x = Fittings factor (dimensionless)

C = Equivalent length : diameter coefficient of a particular pipe fitting

A = Flow area (m^2)

Q = Volumetric flow rate through pipe (m^3.s^{-1})

H = Head of fluid (m)

$H_{friction\_head\_pipe}$ = Frictional head loss through pipe (m)

$H_{friction\_head\_fittings}$ = Frictional head loss through fittings (m)

$H_{friction\_head\_total}$ = Total frictional head loss through pipe and fittings (m)

$H_{static\_head\_loss}$ = Static head loss through system (m)

$H_{total\_head\_loss}$ = Total head loss through system (m)

ΔP = Pressure difference (Pa)

$\Delta P_{friction\_head\_pipe}$ = Frictional pressure loss through pipe (Pa)

$\Delta P_{friction\_head\_fittings}$ = Frictional pressure loss through fittings (Pa)

$\Delta P_{friction\_head\_total}$ = Total frictional pressure loss through pipe and fittings (Pa)

$\Delta P_{static\_head\_loss}$ = Static pressure loss through system (Pa)

$\Delta P_{total\_head\_loss}$ = Total pressure loss through system (Pa)

Example 1

The following example was adapted from Crane Technical Paper 410M “Flow of Fluids Through Valves, Fittings and Pipes” Example 1 Page 3-10.

Description:

Water at 90C flows through a 4 inch Schedule 40 new steel pipe at 92000 kg/hr.

Fluid density = 965
Fluid viscosity = 0.31 cP

Requirement:

Find the pressure drop per 100 metres of pipe.

Solution:

Calculated pressure drop per 100 metres of pipe = 0.83 bar (cf: 0.85 bar published in Crane)

The published result in Crane is slightly higher due to the use of an approximated friction factor of 0.017 rather than the more accurate value of 0.01694 used in the calculator.

Incompressible Flow Calculator Screenshot Example 1:

LINE DETAILS

From	T-1000
To	T-1001
Line Number	Line 1

FLUID PROPERTIES

Fluid		Water	
Phase		Liquid	
Flow rate	m	92000.00	kg/hr
Density	ρ	965.00	kg/m3
Viscosity	μ	0.3100	cP

ELEVATIONS

Line inlet centreline elevation	z_{in}	0.00	m
Line outlet centreline elevation	z_{out}	0.00	m

PIPELINES

		Pipe 1	Pipe 2	Pipe 3	
Pipe nominal diameter		4	3	4	inch
Pipe schedule		Sch 40	Sch 40	Sch 40	
Pipe internal diameter	d	102.3	77.9	102.3	mm
Pipe length	L	100	0	0	m
Absolute roughness	e	0.046	0.046	0.046	mm

FITTINGS

Quantities	Pipe 1	Pipe 2	Pipe 3
90° LR bends	0	0	0
90° Std elbows	0	0	0
45° LR bends	0	0	0
45° Std elbows	0	0	0

Straight tees (flow thro' run)	0	0	0
Straight tees (flow thro' branch)	0	0	0
Pipe entrances	0	0	0
Pipe exits	0	0	0
Pipe contractions	0	0	0
Pipe expansions	0	0	0
Gate valves	0	0	0
Globe valves	0	0	0
Swing check valves	0	0	0
Lift check valves	0	0	0
Tilting disc check valves	0	0	0
Stop check valves	0	0	0
Poppet foot valves (with strainers)	0	0	0
Hinged disc foot valves (with strainers)	0	0	0
Ball valves	0	0	0
Butterfly valves	0	0	0
Plug valves	0	0	0

Miscellaneous losses (no. of velocity heads)	0	0	0

Fittings factor	1	1	1

OUTPUTS

Volumetric flow rate Q 95.337 m3/hr

		Pipe 1	Pipe 2	Pipe 3	
Relative roughness	e:d	0.00045	0.00059	0.00045	
Flow area	A	0.00822	0.00477	0.00822	m2
Velocity	u	3.22	5.56	3.22	m/s
Reynolds No.	Re	1026025	1347399	1026025	
Flow regime		turbulent	turbulent	turbulent	
Friction factor	f	0.01694	0.01776	0.01694	
Pipe velocity head loss	K_{pipe}	16.554	0.000	0.000	
Fittings total velocity head loss	$K_{fittings}$	0.000	0.000	0.000	
Frictional pressure loss	$\Delta P_{friction}$	0.83	0.00	0.00	bar
Frictional head loss	$H_{friction}$	8.76	0.00	0.00	m

Static pressure loss ΔP_{static} 0.00 bar

Static head loss	H_{static}	0.00	m
Total pressure loss	ΔP_{total}	**0.83**	**bar**
Total head loss	H_{total}	**8.76**	**m**

Example 2

The following example was adapted from Crane Technical Paper 410M “Flow of Fluids Through Valves, Fittings and Pipes” Example 4-14 Page 4-8.

Description:

Water at 15C is flowing through a piping system consisting of the following components at a flow rate of 1500 litres per minute:

- 4” Schedule 40 pipe, 34 m long
- 4” x 5” reducing welding elbow (r:d = 1.5)
- 5” Schedule 40 pipe, 67 m long
- 5” 90° welding elbow (r:d = 1.5)

Inlet elevation = 0 m
Outlet elevation = 22 m
Fluid density = 999 kg/m^3
Fluid viscosity = 1.1 cP

Requirement:

Find the fluid velocity in both the 4” and 5” pipes and the pressure difference between the system inlet and outlet.

Solution:

Flow rate = 1500 lpm = 1.5 x 999 x 60 = 89910 kg/hr

4” x 5” reducing welding elbow modelled as 1 pipe expansion and a 5” LR 90° elbow

Calculated velocity in 4” pipe = 3.04 m/s (cf: 3.04 m/s published in Crane)

Calculated velocity in 5” pipe = 1.94 m/s (cf: 1.94 m/s published in Crane)

Calculated pressure difference = 2.66 bar (cf: 2.6 bar published in Crane)

The calculated result is slightly higher than the published result in Crane due to the use of a more conservative value of the resistance coefficient of a 4” x 5” expansion of 1 in the calculator compared to 0.32 used in Crane.

Incompressible Flow Calculator Screenshot Example 2:

LINE DETAILS

From	T-1000
To	T-1001
Line Number	Line 1

FLUID PROPERTIES

Fluid		Water	
Phase		Liquid	
Flow rate	m	89910.00	kg/hr
Density	ρ	999.00	kg/m3
Viscosity	μ	1.1000	cP

ELEVATIONS

Line inlet centreline elevation	z_{in}	0.00	m
Line outlet centreline elevation	z_{out}	22.00	m

PIPELINES

		Pipe 1	Pipe 2	Pipe 3	
Pipe nominal diameter		4	5	4	inch
Pipe schedule		Sch 40	Sch 40	Sch 40	
Pipe internal diameter	d	102.3	128.2	102.3	mm
Pipe length	L	34	67	0	m
Absolute roughness	e	0.046	0.046	0.046	mm

FITTINGS

Quantities	Pipe 1	Pipe 2	Pipe 3
90° LR bends	0	2	0
90° Std elbows	0	0	0
45° LR bends	0	0	0
45° Std elbows	0	0	0

Straight tees (flow thro' run)	0	0	0
Straight tees (flow thro' branch)	0	0	0
Pipe entrances	0	0	0
Pipe exits	0	0	0
Pipe contractions	0	0	0
Pipe expansions	1	0	0
Gate valves	0	0	0
Globe valves	0	0	0
Swing check valves	0	0	0
Lift check valves	0	0	0
Tilting disc check valves	0	0	0
Stop check valves	0	0	0
Poppet foot valves (with strainers)	0	0	0
Hinged disc foot valves (with strainers)	0	0	0
Ball valves	0	0	0
Butterfly valves	0	0	0
Plug valves	0	0	0

Miscellaneous losses (no. of velocity heads)	0	0	0

Fittings factor	1	1	1

OUTPUTS

Volumetric flow rate Q 90.000 m3/hr

		Pipe 1	Pipe 2	Pipe 3	
Relative roughness	e:d	0.00045	0.00036	0.00045	
Flow area	A	0.00822	0.01291	0.00822	m2
Velocity	u	3.04	1.94	3.04	m/s
Reynolds No.	Re	282584	225494	282584	
Flow regime		turbulent	turbulent	turbulent	
Friction factor	f	0.01812	0.01793	0.01812	
Pipe velocity head loss	K_{pipe}	6.022	9.371	0.000	
Fittings total velocity head loss	$K_{fittings}$	1.000	0.448	0.000	
Frictional pressure loss	$\Delta P_{friction}$	0.32	0.18	0.00	bar
Frictional head loss	$H_{friction}$	3.31	1.88	0.00	m

Static pressure loss ΔP_{static} 2.16 bar

Static head loss	H_{static}	22.00	m
Total pressure loss	ΔP_{total}	**2.66**	**bar**
Total head loss	H_{total}	**27.19**	**m**

Example 3

The following example was adapted from Crane Technical Paper 410M “Flow of Fluids Through Valves, Fittings and Pipes” Example 4-9 Page 4-5.

Description:

S.A.E. 70 Lube Oil at 40C is flowing through a piping system consisting of the following components at a flow rate of 2300 litres per minute:

- 5” Schedule 40 pipe, 85 m long
- 5” gate valve with full area seat wide open
- 5” steel angle valve with full area seat wide open
- 5” welding elbow (r:d = 1)

Inlet elevation = 0 m
Outlet elevation = 15 m
Fluid density = 899 kg/m^3
Fluid viscosity = 450 cP

Requirement:

Find the fluid velocity in both the pipe and the pressure difference between the system inlet and outlet.

Solution:

Flow rate = 2300 lpm = 2.3 x 899 x 60 = 124062 kg/hr

5” steel angle valve with full area seat wide open modelled as a miscellaneous fitting with a velocity head loss resistance coefficient of 2.4 as per Crane example.

Calculated velocity in 5” pipe = 2.97 m/s (cf: 2.97 m/s published in Crane)

Calculated pressure difference = 3.65 bar (cf: 3.64 bar published in Crane)

Incompressible Flow Calculator Screenshot Example 3:

LINE DETAILS

From	T-1000
To	T-1001
Line Number	Line 1

FLUID PROPERTIES

Fluid		Lube Oil	
Phase		Liquid	
Flow rate	m	124062.00	kg/hr
Density	ρ	899.00	kg/m3
Viscosity	μ	450.0000	cP

ELEVATIONS

Line inlet centreline elevation	z_{in}	0.00	m
Line outlet centreline elevation	z_{out}	15.00	m

PIPELINES

		Pipe 1	Pipe 2	Pipe 3	
Pipe nominal diameter		5	4	4	inch
Pipe schedule		Sch 40	Sch 40	Sch 40	
Pipe internal diameter	d	128.2	102.3	102.3	mm
Pipe length	L	85	0	0	m
Absolute roughness	e	0.046	0.046	0.046	mm

FITTINGS

Quantities	Pipe 1	Pipe 2	Pipe 3
90° LR bends	0	0	0
90° Std elbows	1	0	0
45° LR bends	0	0	0
45° Std elbows	0	0	0

Straight tees (flow thro' run)	0	0	0
Straight tees (flow thro' branch)	0	0	0
Pipe entrances	0	0	0
Pipe exits	0	0	0
Pipe contractions	0	0	0
Pipe expansions	0	0	0
Gate valves	1	0	0
Globe valves	0	0	0
Swing check valves	0	0	0
Lift check valves	0	0	0
Tilting disc check valves	0	0	0
Stop check valves	0	0	0
Poppet foot valves (with strainers)	0	0	0
Hinged disc foot valves (with strainers)	0	0	0
Ball valves	0	0	0
Butterfly valves	0	0	0
Plug valves	0	0	0

Miscellaneous losses (no. of velocity heads)	2.4	0	0

Fittings factor	1	1	1

OUTPUTS

Volumetric flow rate Q 138.000 m3/hr

		Pipe 1	Pipe 2	Pipe 3	
Relative roughness	e:d	0.00036	0.00045	0.00045	
Flow area	A	0.01291	0.00822	0.00822	m2
Velocity	u	2.97	4.66	4.66	m/s
Reynolds No.	Re	761	953	953	
Flow regime		laminar	laminar	laminar	
Friction factor	f	0.08415	0.06715	0.06715	
Pipe velocity head loss	K_{pipe}	55.791	0.000	0.000	
Fittings total velocity head loss	$K_{fittings}$	3.008	0.000	0.000	
Frictional pressure loss	$\Delta P_{friction}$	2.33	0.00	0.00	bar
Frictional head loss	$H_{friction}$	26.43	0.00	0.00	m

Static pressure loss ΔP_{static} 1.32 bar

Static head loss	H_{static}	15.00	m
Total pressure loss	ΔP_{total}	**3.65**	**bar**
Total head loss	H_{total}	**41.43**	**m**