

Calculation of Pipe Friction Loss

Engineering Management Group
Development Planning Department
Standard Pump Business Division

EBARA corporation

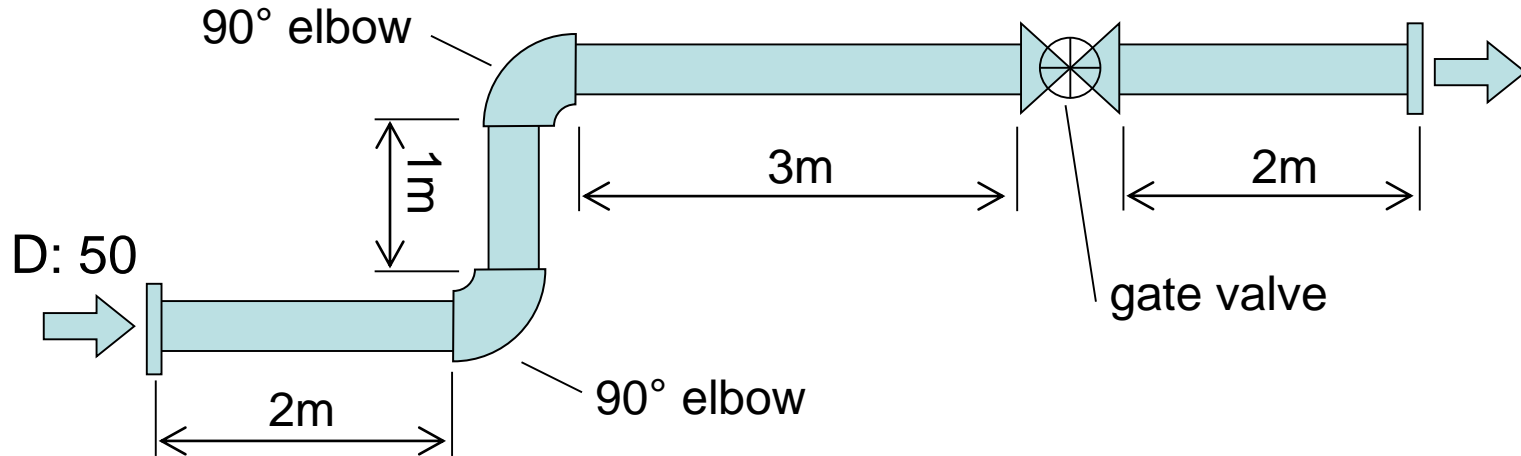
October 16th, 2013

1. Work flow of pipe calculation

- (1) Adding up actual straight length of piping
- (2) Count number of piping elements (pipe joints, valves and so on)
- (3) Convert these piping elements to equivalent length of straight pipe
- (4) Add the equivalent length of straight pipe to the actual straight length
- (5) Calculate pipe resistance by using calculation method or graphical method.

2. Equivalent Length of Straight Pipe

Example A



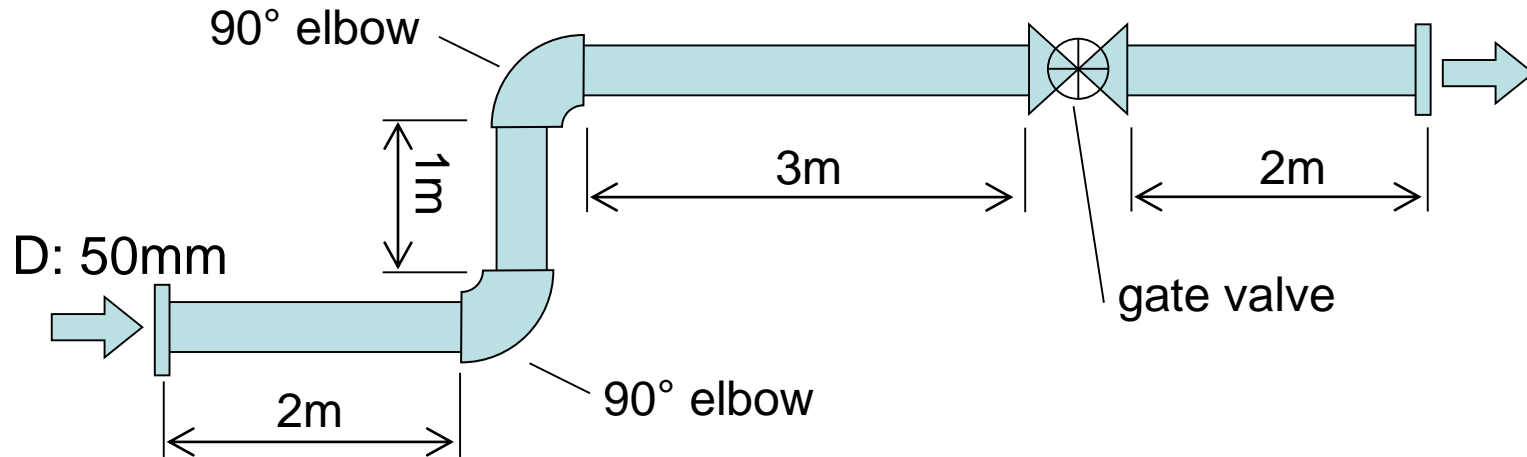
(1) Integrate of actual straight length of piping

$$2\text{ m} + 1\text{ m} + 3\text{ m} + 2\text{ m} = 8\text{ m}$$

2. Equivalent Length of Straight Pipe

Example A

Top View
(There is no difference in height.)



(2) Count the number of piping elements (pipe joints, valves and so on)

	90° elbow	2
	gate valve	1

2. Equivalent Length of Straight Pipe

+ Piping element loss

The table below shows the straight pipe equivalent length that produces the same friction loss caused by piping elements.

unit : m

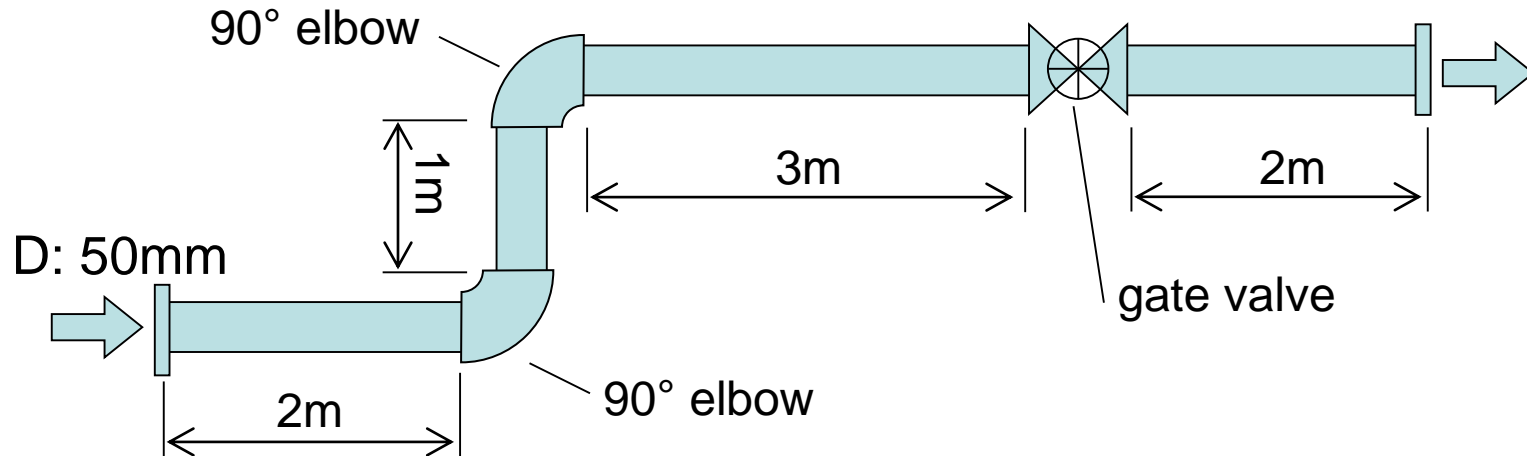
Pipe element \ Pipe dia. (mm)	25	32	40	50	65	80	100	125	150	200	250
90° elbow	0.5	0.6	0.7	0.9	1.1	1.3	1.8	2.2	2.7	3.7	4.3
90° bend	0.5	0.6	0.7	0.8	0.9	1.0	1.3	1.5	1.7	2.1	2.4
Globe valve	13.7	16.5	18.0	21.3	23.5	28.6	36.5	—	—	—	—
Gate valve	—	—	—	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0
Check/ foot valve	2.2	3.1	3.7	5.2	6.4	8.2	11.6	15.2	19.2	27.4	36.6

[Hydraulic Institute]



2. Equivalent Length of Straight Pipe

Example A

Top View
(There is no difference in height.)



(3) Convert these piping elements to equivalent length of straight pipe

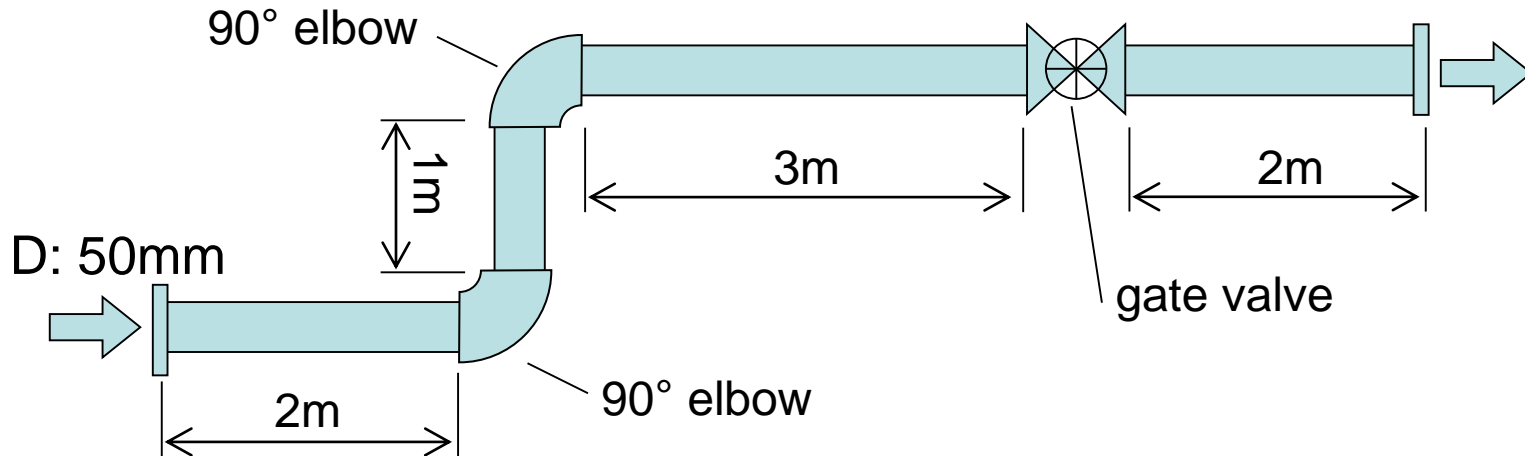
	90° elbow	2	...	$0.9 \text{ m} \times 2 = 1.8 \text{ m}$
	gate valve	1	...	$0.8 \text{ m} \times 1 = 0.8 \text{ m}$

2.6 m

2. Equivalent Length of Straight Pipe

Example A

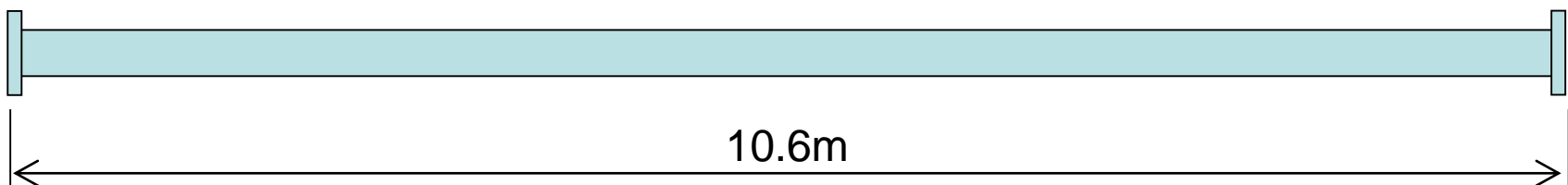
Top View
(There is no difference in height.)



(1) Integrate of actual straight length of piping 8m

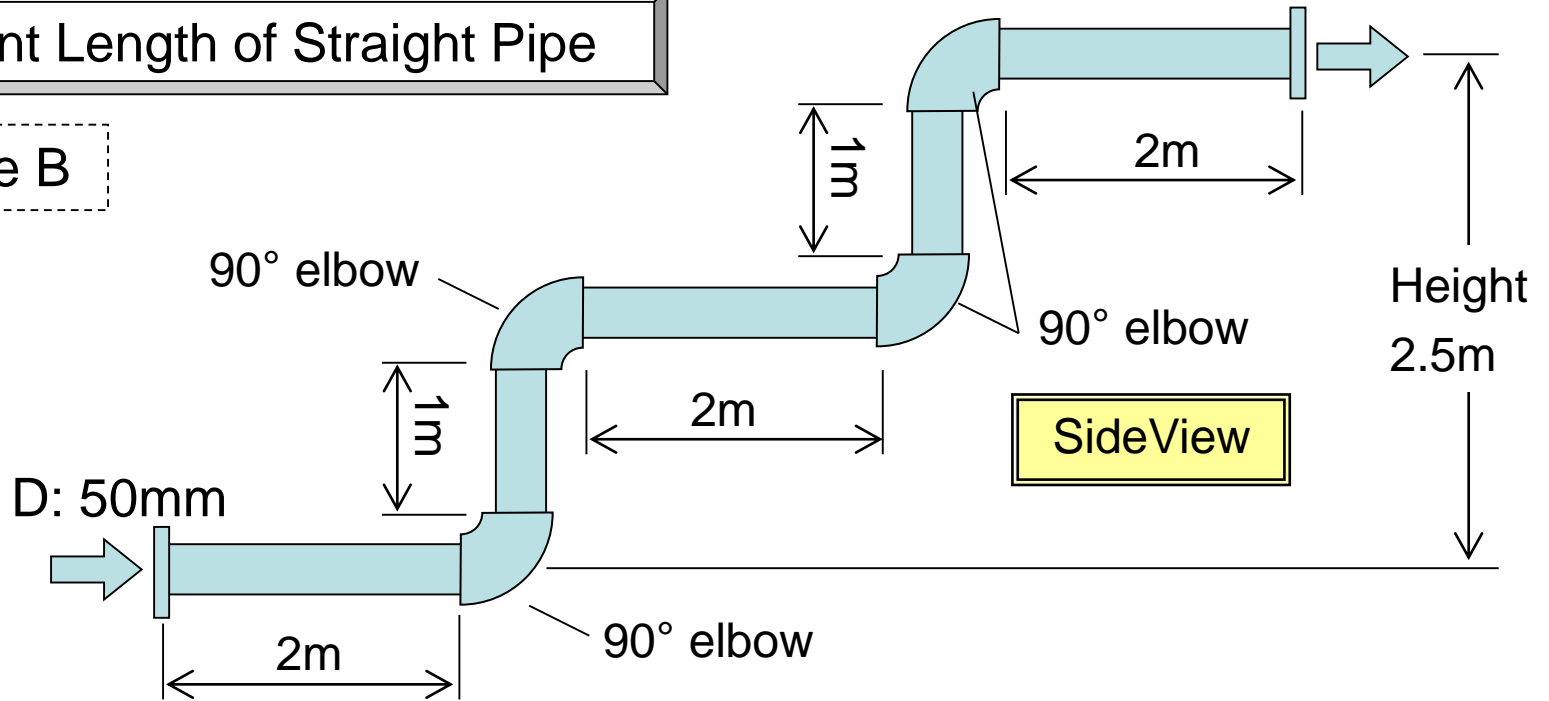
(3) equivalent length of straight pipe of piping elements 2.6 m

→ Total straight pipe length 10.6 m



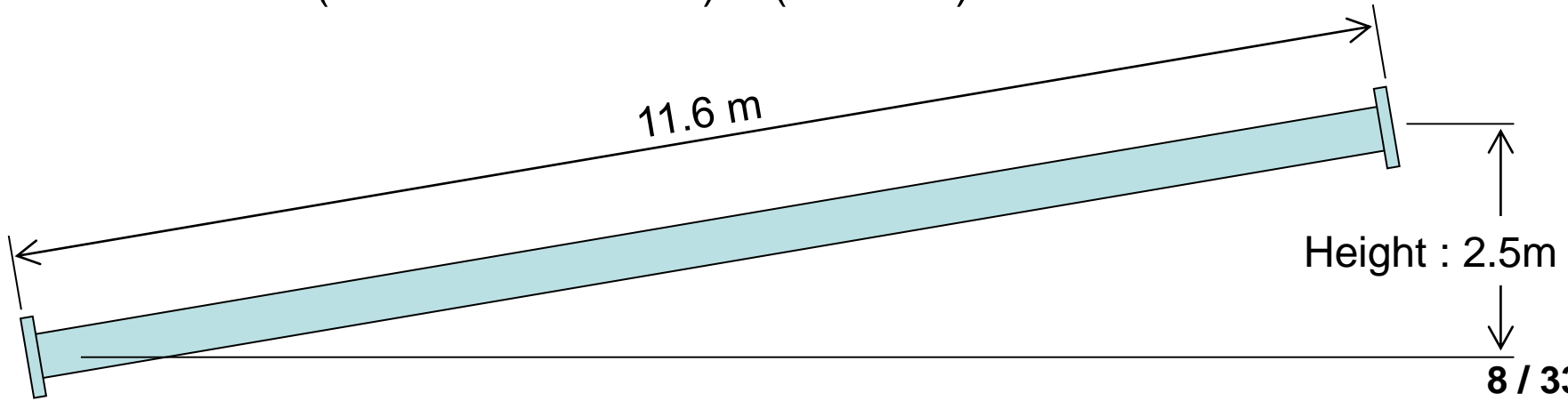
2. Equivalent Length of Straight Pipe

Example B



Total straight pipe length

$$(2 + 1 + 2 + 1 + 2) + (0.9 \times 4) = 11.6 \text{ m}$$



3. Head Loss for Straight Pipe (Calculation Method)

There are several methods to calculate the pipe friction loss. Among them, the following Darcy-Weisbach equation is commonly used.

$$H_f = \lambda \times \frac{L}{D} \times \frac{V^2}{2g} \quad (\text{Darcy-Weisbach equation})$$

$$V = \frac{Q}{\frac{\pi}{4} \times D^2 \times 60} = 0.0212 \times \frac{Q}{D^2}$$

L: Pipe length (m)

D: Pipe inner diameter (m)

V: Flow velocity in pipe (m/s)

g: Gravity acceleration (9.8 m/s²)

Q: Flow rate (m³/min)

H_f: Head loss (m)

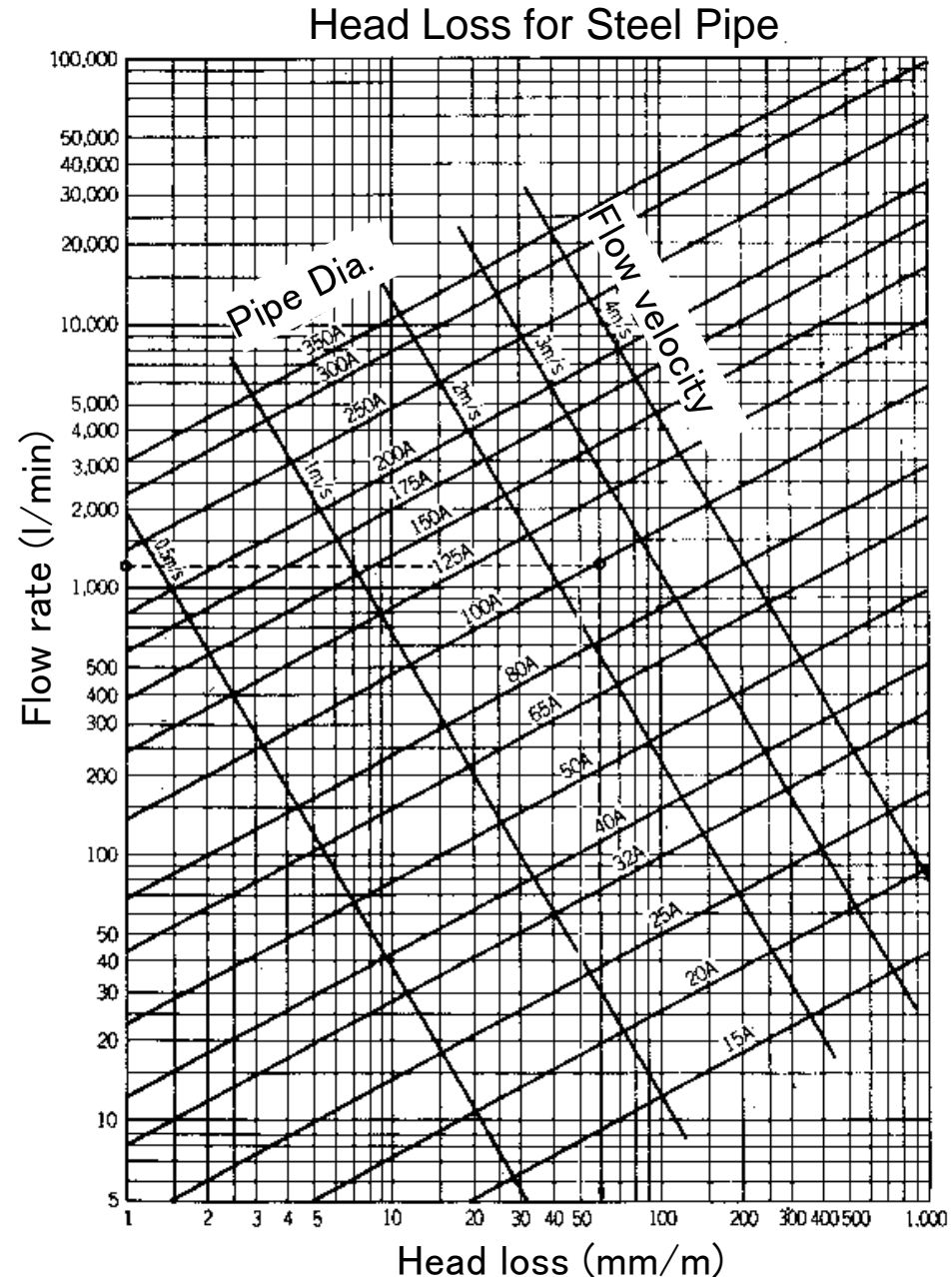
λ: Loss coefficient (Value variable with fluid viscosity, flow velocity, and diameter/surface roughness of the pipe). The loss coefficient can be obtained using the following equation that assumes water in a new steel pipe.

$$\lambda = 0.02 + \frac{1}{2000 \times D}$$

4. Head Loss for Straight Pipe (Graphical Method)

The head loss for steel pipe are as shown in the graph on the right. This graph however, indicate the head loss per meter for new pipe, and therefore the result obtained must be translated into the length as desired.

Taking into consideration an increase of friction loss caused by aging of the inner pipe wall, the obtained value is generally multiplied by 1.5.

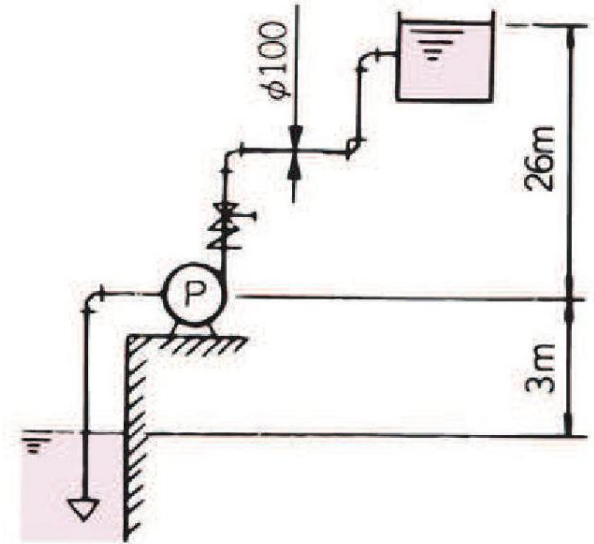


4. Head Loss Calculation

+ Example Solution

Given information

Pipe Size :	100mm
Straight pipe Length:	80m
Foot Valve :	1pcs
90° Elbow :	4pcs
Check Valve :	1pcs
Gate Valve :	1pcs
Pipe :	Steel
Flow rate :	1.2m ³ /min



To find the friction loss head

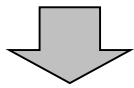
Straight pipe length :	80m
Equivalent straight pipe length on piping elements :	31.3 m
Foot Valve :	11.6 x 1 = 11.6
90° Elbow :	1.8 x 4 = 7.2
Check Valve :	11.6 x 1 = 11.6
Gate Valve :	0.9 x 1 = 0.9

Equivalent total straight length: 111.3m

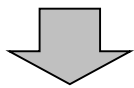
4. Head Loss Calculation

+ Graphical Method

Flow rate : $1.2\text{m}^3/\text{min}$
Head Loss (This reads in the graph):
 0.06 mm/m



Total friction head loss :
 $0.06 \times 111.3 = 6.7\text{ m}$



$$\begin{aligned}\text{Total head} &= H_a + H_f \\ &= (3 + 26) + 6.7 \\ &= 35.7\text{ m}\end{aligned}$$

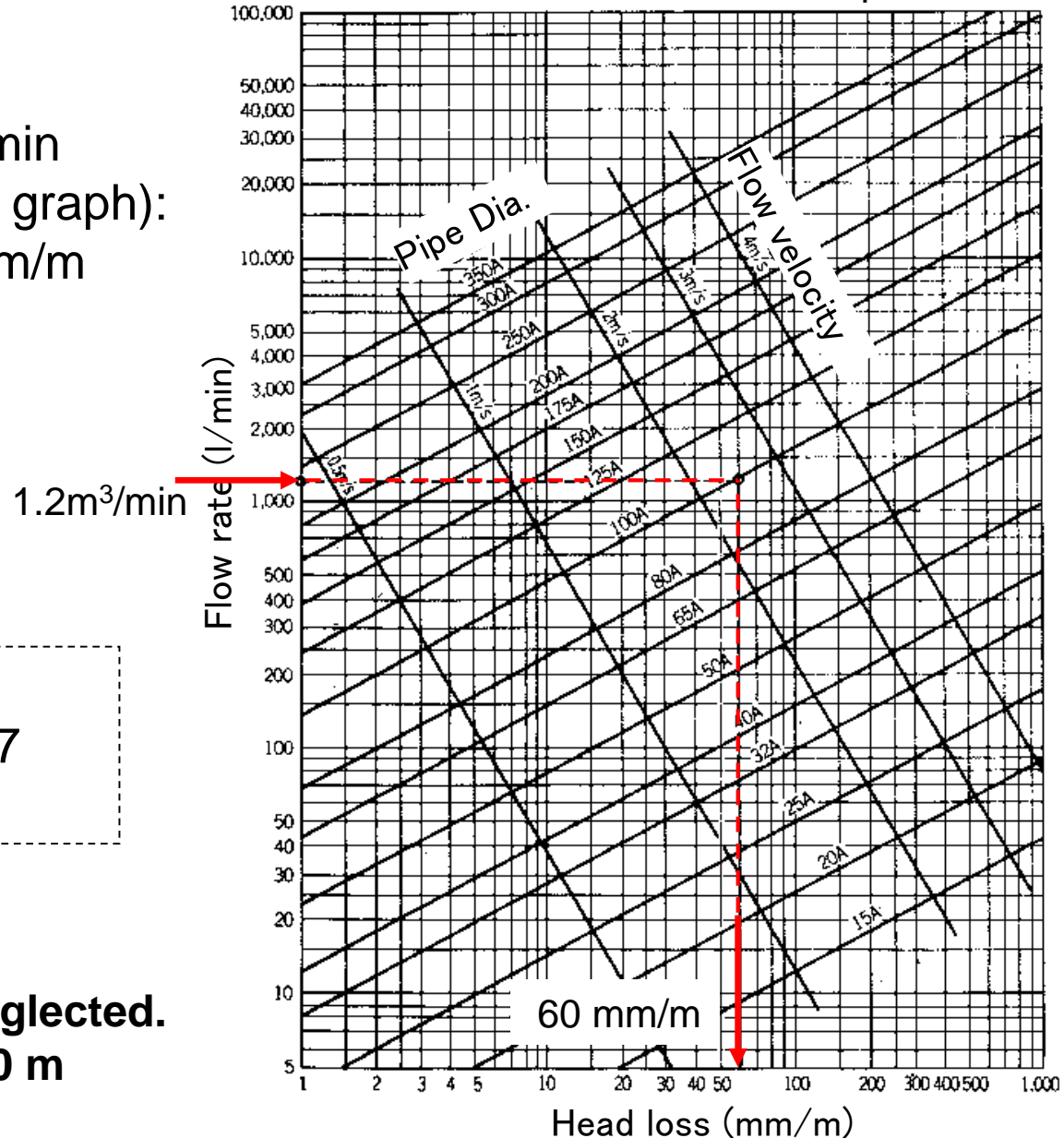
H_a : Actual Head

H_f : Friction Head Loss

***) Velocity Head ($V^2/2g$) is Neglected.**

If include, Total Head = 36.0 m

Head Loss for Steel Pipe



4. Head Loss Calculation

+ Calculation Method

Dia.100 Steel Pipe :

external dia. : 114.3mm

thickness : 4.5mm -> internal dia. : 105.3mm

$$\lambda = 0.02 + \frac{1}{2000 \times D} = 0.02 + \frac{1}{2000 \times 0.153} = 0.0247$$

$$V = 0.0212 \times \frac{Q}{D^2} = 0.0212 \times \frac{1.2}{0.1053^2} = 2.29 \text{ m/sec}$$

Total friction head loss :

$$H_f = \lambda \times \frac{L}{D} \times \frac{V^2}{2g} = 0.0247 \times \frac{111.3}{0.1053} \times \frac{2.29^2}{2 \times 9.8} = 7.0 \text{ m}$$

$$\begin{aligned} \text{Total head} &= H_a + H_f \\ &= (3 + 26) + 7.0 \\ &= 36.0 \text{ m} \end{aligned}$$

H_a : Actual Head

H_f : Friction Head Loss

***) Velocity Head ($V^2/2g$) is Neglected.**

If include, Total Head = 36.3 m

SPAIX Pipe Calculation

5. Case Study (1) [Calculation]

D: 50mm

11.6 m

Height : 2.5m

Dia.50 Steel Pipe :

external dia. : 60.5mm

thickness : 3.8mm -> internal dia. : 52.9mm

Pipe Size :

50mm

Straight pipe Length:

11.6m

Flow rate :

0.3m³/min

$$\lambda = 0.02 + \frac{1}{2000 \times D} = 0.02 + \frac{1}{2000 \times 0.0529} = 0.0295$$

$$V = 0.0212 \times \frac{Q}{D^2} = 0.0212 \times \frac{0.3}{0.0529^2} = 2.27 \text{ m/sec}$$

Total friction head loss :

$$H_f = \lambda \times \frac{L}{D} \times \frac{V^2}{2g} = 0.0295 \times \frac{11.6}{0.0529} \times \frac{2.27^2}{2 \times 9.8} = 1.70 \text{ m}$$

$$\text{Total head} = H_a + H_f = 2.50 + 1.70 = 4.20 \text{ m}$$

H_a : Actual Head

H_f : Friction Head Loss

***) Velocity Head (V²/2g) is Neglected. If include, Total Head = 4.46 m**

5. Case Study (1) [by SPAIX]

The screenshot displays the 'Spaix 2 Pipe Calc' software interface. The main window is titled 'Spaix 2 Pipe Calc [Untitled]' and features a menu bar with 'File', 'Edit', 'Settings', and '?'. Below the menu bar is a toolbar with icons for 'New', 'Open project...', 'Save project', 'Language...', 'Units...', 'Directories...', and 'Help...'. The 'Units...' button is highlighted with a red dashed box, and a red arrow points from it to the 'Spaix 2 Pipe Calc - Units' dialog box.

The 'Spaix 2 Pipe Calc - Units' dialog box is open, showing the 'Units' tab. It has three radio buttons for 'Type': 'SI-units', 'US-units', and 'User-defined'. The 'User-defined' option is selected. Below the type selection is a list of units for various parameters, each with a dropdown menu. The units are:

Parameter	Unit
Head	m
Rated power	kW
Dimensions	mm
Density	kg/m ³
Pressure	kPa
Electric current	A
Moment of inertia	kg m ²
Specific heat	J/(kg K)
Area	mm ²
Specific drain flow	l/(s ha)
Velocity	m/s
Air flow	l/s
Micro dimension	µm
Flow	m ³ /min
Speed	1/min
Temperature	°C
Kin. viscosity	mm ² /s
Electric voltage	V
Weight	kg
Torque	Nm
Sound pressure level	dB
Force	N
Discharge area	ha
Volume	l
Mass flow	kg/h
Dynamic viscosity	mPa s

The dialog box also includes 'Ok', 'Cancel', and 'Help' buttons at the bottom. The main software interface shows 'Medium data' (Pumped fluid: Stormwater, Drinking water, Domestic waste water, Others), 'Flow' (Total flow: 0, No. of pumps: 1), and 'Pressure loss' (Standard, Total head: H_{geo}).

5. Case Study (1) [by SPAIX]

The screenshot shows the 'Spaix 2 Pipe Calc' software interface. The window title is 'Spaix 2 Pipe Calc [Untitled]'. The menu bar includes 'File', 'Edit', 'Settings', and '?'. The toolbar contains icons for 'New', 'Open project...', 'Save project', 'Language...', 'Units...', 'Directories...', and 'Help...'. The 'Vsx' logo and 'VOGEL SOFTWARE' are visible in the top left. The interface is divided into several sections:

- Medium data:** Includes 'Pumped fluid' with radio buttons for 'Stormwater', 'Drinking water' (selected), 'Domestic waste water', and 'Others'.
- Flow:** Contains input fields for 'Total flow' (0.3 m³/min) and 'No. of pumps' (1). A red dashed box highlights these fields. Below them, it shows 'Flow / no. of pumps' as 0.3 m³/min.
- Properties:** A dropdown menu is set to 'Water, clean'. A vertical temperature scale is on the right. The properties listed are:
 - Temperature: 20 °C
 - Density: 998.3 kg/m³
 - Viscosity: 1.003 mm²/s
 - Vapour pressure: 2.337 kPa
 - Concentration: 100 %
- Pressure loss:** Includes a 'Standard' tab, 'Total head' (0 m), and 'Calculation model' (COLEBROOK). A diagram shows a pipe with a vertical height H_{geo} (0 m) and a pressure rise H_v (0 m). Below the diagram, 'Pressure rise' is set to 0 kPa.

At the bottom right, there are 'Ok' and 'Cancel' buttons.

5. Case Study (1) [by SPAIX]

Friction head

General

Operating limits			Piping	
Permissible diameter (absolute)	25 ... 1000	mm	Pumped fluid	Drinking water
Permissible diameter	32 ... 1000	mm	Flow	0.3 m ³ /min
Permissible velocity	1.5 ... 5	m/s	Recommended nominal diameter	65 mm
			Flow velocity	1.507 m/s

List

Piping
 Elbows
 Transitions
 Isolating valves
 Non-return valves
 Other fittings
 Sundry head losses

Material	Standard	DN	PN	di/ mm	v/ m/s	L/ m	k/ mm	Hv/ m
Cast iron	-	DN 80 (3")	-	79.76	1	10	0.26	0.181
Steel	DIN 2440	DN 50	-	53	2.27	11.6	0.25	1.755

Friction head 1.755 m
Total friction head 1.755 m

5. Case Study (1) [by SPAIX]

Spaix 2 Pipe Calc [Untitled]

File Edit Settings ?

New Open project... Save project Language... Units... Directories... Help...

Medium data

Pumped fluid

- Stormwater
- Drinking water
- Domestic waste water
- Others

Flow

Total flow m³/min

No. of pumps

Flow / no. of pumps 0.3 m³/min

Properties

Temperature °C

Density kg/m³

Viscosity mm²/s

Vapour pressure kPa

Concentration %

Pressure loss

Standard

Total head m

Calculation model

H_{geo} m

H_v m

Pressure rise kPa

Ok Cancel

VSX VOGEL SOFTWARE

View

Calculate system

Data sheets

Calculated

Variants

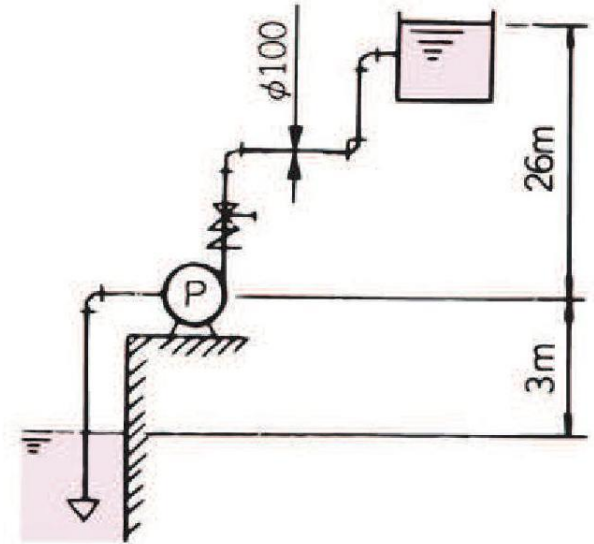
- Calculation 1

6. Case Study (2) [Calculation]

+ Example Solution

Given information

Pipe Size :	100mm
Straight pipe Length:	80m
Foot Valve :	1pcs
90° Elbow :	4pcs
Check Valve :	1pcs
Gate Valve :	1pcs
Pipe :	Steel
Flow rate :	1.2m ³ /min



To find the friction loss head :

Straight pipe length :	80m
Equivalent straight pipe length on piping elements :	31.3 m
Foot Valve :	11.6 x 1 = 11.6
90° Elbow :	1.8 x 4 = 7.2
Check Valve :	11.6 x 1 = 11.6
Gate Valve :	0.9 x 1 = 0.9

Equivalent total straight length: 111.3m

6. Case Study (2) [Calculation]

+ Calculation Method

Dia.100 Steel Pipe :

external dia. : 114.3mm

thickness : 4.5mm -> internal dia. : 105.3mm

$$\lambda = 0.02 + \frac{1}{2000 \times D} = 0.02 + \frac{1}{2000 \times 0.153} = 0.0247$$

$$V = 0.0212 \times \frac{Q}{D^2} = 0.0212 \times \frac{1.2}{0.1053^2} = 2.29 \text{ m/sec}$$

Total friction head loss :

$$H_f = \lambda \times \frac{L}{D} \times \frac{V^2}{2g} = 0.0247 \times \frac{111.3}{0.1053} \times \frac{2.29^2}{2 \times 9.8} = 7.00 \text{ m}$$

$$\begin{aligned} \text{Total head} &= H_a + H_f \\ &= (3 + 26) + 7.0 \\ &= 36.0 \text{ m} \end{aligned}$$

H_a : Actual Head

H_f : Friction Head Loss

***) Velocity Head (V²/2g) is Neglected.**

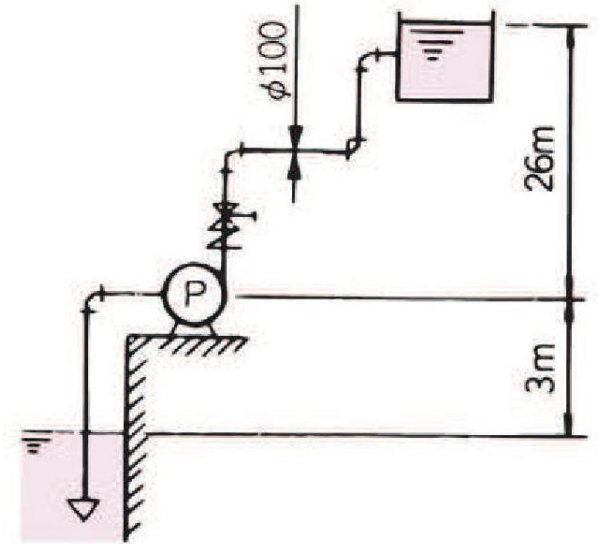
If include, Total Head = 36.27 m

6. Case Study (2) [Calculation]

+ Example Solution

Given information

Pipe Size :	100mm
Straight pipe Length:	80m
Foot Valve :	1pcs
90° Elbow :	4pcs
Check Valve :	1pcs
Gate Valve :	1pcs
Pipe :	Steel
Flow rate :	1.2m ³ /min




6. Case Study (2) [by SPAIX]

Spaix 2 Pipe Calc [Untitled]

File Edit Settings ?

New Open project... Save project Language... Units... Directories... Help...



View

Calculate system

Data sheets

Calculated

Variants

- Calculation 1

Medium data

Pumped fluid

Stormwater
 Drinking water
 Domestic waste water
 Others

Flow

Total flow m³/min

No. of pumps

Flow / no. of pumps 1.2 m³/min

Properties

Water, clean

Temperature °C

Density kg/m³

Viscosity mm²/s

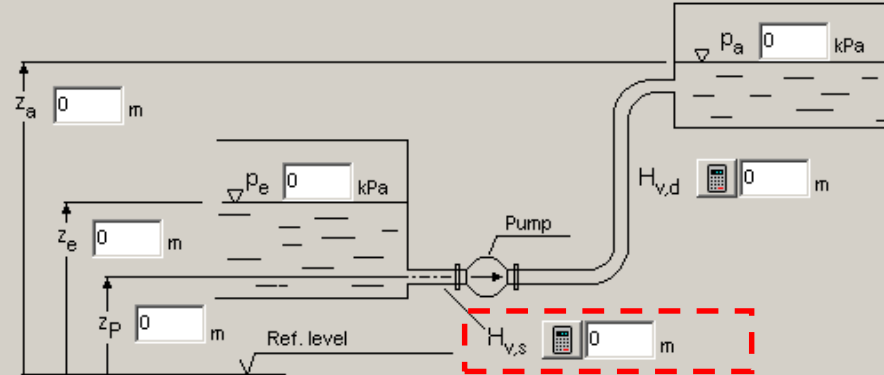
Vapour pressure kPa

Concentration %

Pressure loss

Standard Line system Submersible pump system Cooling system Drinking water plant Closed circulating

Total head m Calculation model COLEBROOK



z_a m
 p_a kPa
 z_e m
 p_e kPa
 z_p m
 $H_{v,d}$ m
 $H_{v,s}$ m
 Ref. level

Ok Cancel

6. Case Study (2) [by SPAIX]

Friction head
_ □ ×

General

Operating limits			Piping	
	Permissible diameter (absolute)	25 ... 1000 mm	Pumped fluid	Drinking water
	Permissible diameter	32 ... 1000 mm	Flow	1.2 m ³ /min
	Permissible velocity	1.5 ... 5 m/s	Recommended nominal diameter	125 mm
			Flow velocity	1.63 m/s

List

≡ Piping ⤵ Elbows ⤵ Transitions ⤵ Isolating valves ⤵ Non-return valves ⤵ Other fittings Sundry head losses

DN	PN	Supplier	Name	ξ	Quantity	Hv/ m
DN 100	-	-	Foot valve	3	1	0.992
DN 100	-	-	Foot valve	3	1	0.992

	Friction head	0.992 m
	Total friction head	0.992 m

✓ Ok

✗ Cancel

? Help




6. Case Study (2) [by SPAIX]

Friction head
_ □ ×

General

Operating limits			Piping	
Permissible diameter (absolute)	25 ... 1000	mm	Pumped fluid	Drinking water
Permissible diameter	32 ... 1000	mm	Flow	1.2 m ³ /min
Permissible velocity	1.5 ... 5	m/s	Recommended nominal diameter	125 mm
			Flow velocity	1.63 m/s



List

≡ Piping | ⤵ Elbows | ⤵ Transitions | ⤵ Isolating valves | ⤵ Non-return valves | ⤵ Other fittings | Sundry head losses

Material	Standard	DN	PN	d _i / mm	R/ mm	δ/ °	k/ mm	Quantity	Hv/ m
Steel	DIN 2440	DN 100	-	105.3	100	90	0.25	1	0.148
Steel	DIN 2440	DN 100	-	105.3	100	90	0.25	1	0.148


✓ Ok

✗ Cancel

? Help

Friction head 0.148 m

Total friction head 1.139 m



6. Case Study (2) [by SPAIX]

The screenshot displays the Spaix 2 Pipe Calc software interface. The window title is "Spaix 2 Pipe Calc [Untitled]". The menu bar includes "File", "Edit", and "Settings". The toolbar contains icons for "New", "Open project...", "Save project", "Language...", "Units...", "Directories...", and "Help...".

Medium data

Pumped fluid

- Stormwater
- Drinking water
- Domestic waste water
- Others

Flow

Total flow: 1.2 m³/min
No. of pumps: 1
Flow / no. of pumps: 1.2 m³/min

Properties

Water, clean

Temperature: 20 °C
Density: 998.3 kg/m³
Viscosity: 1.003 mm²/s
Vapour pressure: 2.337 kPa
Concentration: 100 %

Pressure loss

Line system

Total head: 1.139 m
Calculation model: COLEBROOK

The diagram shows a hydraulic system with a pump. The pump head is $H_{v,s} = 1.139$ m. The suction side has a water level at $z_e = 0$ m and a pressure $P_e = 0$ kPa. The discharge side has a water level at $z_a = 0$ m and a pressure $P_a = 0$ kPa. The vertical distance between the suction and discharge levels is $H_{v,d} = 0$ m. A reference level is shown at $z_p = 0$ m. The calculated total head is $H_{v,s} = 1.139$ m, which is highlighted with a red dashed box.

Calculated

Variants

- Calculation 1

Ok

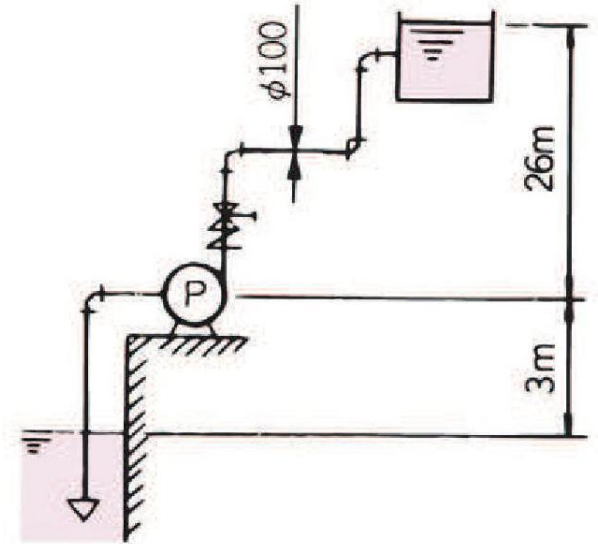
Cancel

6. Case Study (2) [Calculation]

+ Example Solution

Given information

Pipe Size :	100mm
Straight pipe Length:	80m
Foot Valve :	1pcs
90° Elbow :	4pcs
Check Valve :	1pcs
Gate Valve :	1pcs
Pipe :	Steel
Flow rate :	1.2m ³ /min



6. Case Study (2) [by SPAIX]

Friction head
_ □ ×

General

Operating limits			Piping		
	Pumped fluid		Drinking water		
Permissible diameter (absolute)	25 ... 1000	mm	Flow	1.2	m ³ /min
Permissible diameter	32 ... 1000	mm	Recommended nominal diameter	125	mm
Permissible velocity	1.5 ... 5	m/s	Flow velocity	1.63	m/s

List

Piping
Elbows
Transitions
Isolating valves
Non-return valves
Other fittings
Sundry head losses

Material	Standard	DN	PN	di/ mm	v/ m/s	L/ m	k/ mm	Hv/ m	
Cast iron	-	DN 150 (6")	-	450.0	1.42	10	0.25	0.099	+
Steel	DIN 2440	DN 100	-	105.3	2.3	80	0.25	5.141	

Friction head	5.141 m
Total friction head	5.141 m

6. Case Study (2) [by SPAIX]

Friction head
_ □ ×

General

Operating limits			Piping		
				Pumped fluid	Drinking water
Permissible diameter (absolute)	25 ... 1000	mm		Flow	1.2 m ³ /min
Permissible diameter	32 ... 1000	mm		Recommended nominal diameter	125 mm
Permissible velocity	1.5 ... 5	m/s		Flow velocity	1.63 m/s

List

≡ Piping ⤵ Elbows ⤵ Transitions ⤵ Isolating valves ⤵ Non-return valves ⤵ Other fittings Sundry head losses

Material	Standard	DN	PN	di/ mm	R/ mm	δ/ °	k/ mm	Quantity	Hv/ m
Steel	DIN 2440	DN 100	-	105.3	100	90	0.25	3	0.443

✓ Ok

✗ Cancel

? Help

Friction head **0.443 m**

Total friction head **5.584 m**

6. Case Study (2) [by SPAIX]

Friction head
_ □ ×

General

Operating limits			Piping	
	Permissible diameter (absolute)	25 ... 1000 mm	Pumped fluid	Drinking water
	Permissible diameter	32 ... 1000 mm	Flow	1.2 m ³ /min
	Permissible velocity	1.5 ... 5 m/s	Recommended nominal diameter	125 mm
			Flow velocity	1.63 m/s

List

≡ Piping | ⤵ Elbows | ↔ Transitions | ⊞ Isolating valves | ⊞ Non-return valves | ⊞ Other fittings | Sundry head losses

DN	PN	Supplier	Name	ζ	Quantity	Hv/ m
DN 100	-	-	Flap valve	1.8	1	0.595
DN 100	-	-	Flap valve	1.8	1	0.595

Friction head 0.595 m

Total friction head 6.179 m

✓ Ok

✗ Cancel


? Help

6. Case Study (2) [by SPAIX]

Friction head

General

Operating limits			Piping	
Permissible diameter (absolute)	25 ... 1000	mm	Pumped fluid	Drinking water
Permissible diameter	32 ... 1000	mm	Flow	1.2 m ³ /min
Permissible velocity	1.5 ... 5	m/s	Recommended nominal diameter	125 mm
			Flow velocity	1.63 m/s




VSOCL SOFTWARE

List

≡ Piping | ⤵ Elbows | ⤵ Transitions | ⤵ Isolating valves | ⤵ Non-return valves | ⤵ Other fittings | Sundry head losses

DN	PN	Supplier	Name	ζ	Quantity	Hv/ m
DN 400	-	-	Flat slide valve	0.3	1	0.099
DN 100	-	-	Flat slide valve	0.3	1	0.099



Friction head **0.099 m**

Total friction head **6.278 m**

✓ Ok

✗ Cancel

? Help

6. Case Study (2) [by SPAIX]

Spaix 2 Pipe Calc [Untitled]
 File Edit Settings ?

New Open project... Save project Language... Units... Directories... Help...

VOSEL SOFTWARE

View

Calculate system

Data sheets

Calculated

Variants
 Calculation 1

Medium data

Pumped fluid

- Stormwater
- Drinking water
- Domestic waste water
- Others

Flow

Total flow m³/min

No. of pumps

Flow / no. of pumps 1.2 m³/min

Properties

Water, clean

Temperature °C

Density kg/m³

Viscosity mm²/s

Vapour pressure kPa

Concentration %

Pressure loss

Line system

Total head m

Calculation model COLEBROOK

p_a kPa

z_a m

z_e m

z_p m

Ref. level

$H_{v,d}$ m

$H_{v,s}$ m

Pump

Ok

Cancel

END