SERIES PIPING SYSTEM TEST PROBLEMS

The non-proprietary tests used to validate the Series Piping module in INSTED are presented in this chapter. To access the accuracy of INSTED predictions in more detail, consult the original source of the test problems. However, some diagnostic results reported in the sources are presented here and compared with INSTED predictions. You should simulate these test problems before attempting to solve more realistic engineering problems. The input data for the various tests are contained in the distribution disks.

Test Problem 1

➢ **Problem Statement:**

Chloroform flows at a rate of 0.05 m^3/s through a 4-nominal schedule 40 wrought iron pipe. The pipe is laid out horizontally and is 250 m long. Calculate the pressure drop of the chloroform.

For chloroform:

$\rho = 1.47\ (1\ 000)\ kg/m^3$, $\mu = 0.53 \times 10^{-3}\ N{\bullet}s/m^2$

For 4-nominal schedule 40 pipe, Table D.1 shows

ID = 10.23 cm, $A = 82.19\ cm^2$

For wrought iron, ε = 0.004 6 cm.

Source:

William S. Janna. Design of Fluid Thermal Systems. PWS-Kent Publishing Co. Boston, MA, USA. Page 49.

➢ **Comments**

- The task is to calculate pressure.
- Input data in source are used.
- No unit conversion is necessary.
- Problem is straightforward.
- There are no minor losses.

➢ **Results**

In this chapter, 'Δp', f, and Re will be used to denote pressure loss, friction factor, and Reynolds number. The abbreviation '**Diff**.' will be used for the difference between INSTED results and the results from the source.

Variable	**Janna**	**INSTED**	**Diff.**
Δp	0.11 MPa	0.111MPa	< 1%
f	0.0165	0.0167	< 1%
Re	1.73×10^6	1.73×10^6	< 1%

- Name of data file: JANNA.49

The result screen is shown below.

PIPE	Diameter (m)	Velocity (m/s)	Re	friction factor	Minor loss
1	.102E+00	.608E+01	.173E+07	.167E-01	.000E+00

Test Problem 2

- **Problem Statement:**

  A 6-nominal schedule 80 cast iron pipe is 11,270 ft long. It is to convey octane. The available pump can provide a pressure drop of 25 psi. Determine the expected flow rate of octane in the pipes.

For octane,

$$\rho = 0.701(62.4)\ \text{lbm/ft}^3 \ \text{ and } \ \mu = 1.07 \times 10^{-5}\ \text{lbf·s/ft}^2$$

For 6-nominal schedule 80 pipe,

$$ID = 0.4801\ \text{ft} \ \text{ and } \ A = 0.1810\ \text{ft}^2$$

and ε = 0.00085 ft. for cast iron.

Source:
William S. Janna. Design of Fluid Thermal Systems. PWS-Kent Publishing Co. Boston, MA, USA. Page 55.

- **Comments**
  - The task is to calculate flow rate.
  - Input data in source are used.
  - On-line unit conversion capability in INSTED is needed. Remember to enter the dynamic viscosity in lbf.h/ft^2 or lbm/ft.h for your convenience.
  - There are no minor losses.

- **Results**

Variable	**Janna**	**Janna**	**INSTED**	**Diff.**
	British	SI	SI	
Velocity	3.06 ft/s	0.9326 m/s	0.937	<1%
Flow rate	247 gal/min	0.01557 m^3/s	0.01576	<1%
Re	1.9 x 10^5	1.9 x 10^5	1.88 x 10^5	1.1%
f	0.024	0.024	0.0239	<1%

- Name of data file: JANNA.55

- The result screen is presented below.

TRIALS	DIAMETER	FRICTION	VELOCITY	REYNOLDS	F. DIFF
1	.146E+00	.234E-01	.162E+01	.324E+06	-.154E-01
2	.146E+00	.239E-01	.946E+00	.189E+06	-.443E-03
3	.146E+00	.239E-01	.937E+00	.188E+06	-.958E-05

Test Problem 3

- **Problem Statement:**

  A PVC plastic pipeline is to convey fifty liters per second of ethylene glycol over a distance of 2000 m. The available pump can overcome a frictional loss of 200 kPa. Select a suitable size for the pipe.

  For plastic tubing, the source says that is correct to use the "smooth" line of the Moody Diagram. For ethylene glycol,

  $\rho = 1.1(1\ 000)\ kg/m^3$, $\mu = 16.2 \times 10^{-3} N \bullet s/m^2$

  Source:
  William S. Janna. Design of Fluid Thermal Systems. PWS-Kent Publishing Co. Boston, MA, USA. Page 57

- **Comments**
  - The task is to calculate pipe diameter.
  - Input data in source are used.
  - No unit conversion is necessary.
  - The valve $\varepsilon = 10^{-10}$ is used for the absolute roughness.
  - There are no minor losses.

- **Results**

Variable	**Janna**	**INSTED**	**Difference**
friction factor	0.026	0.0261	< 1%
diameter	0.225 m	0.225 m	< 1%

- Name of data file: JANNA.57

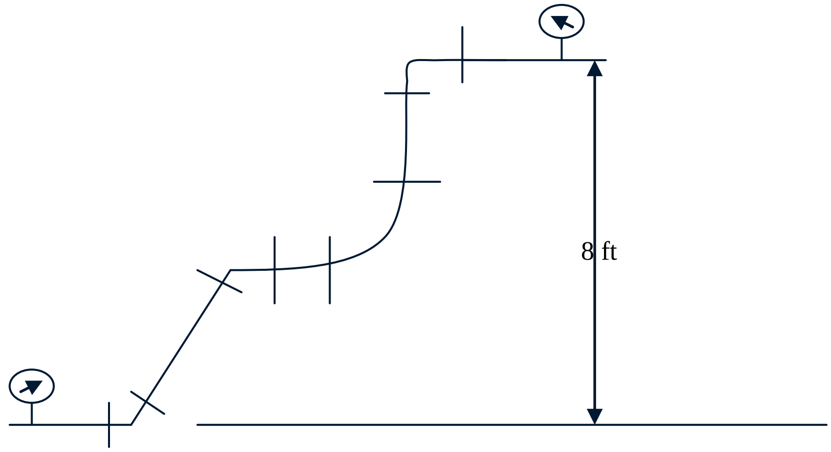
  The result screen is shown below.

TRIAL	DIAMETER	FRICTION	VELOCITY	REYNOLD	F DIFF
1	.178E+00	.246E-01	.201E+01	.243E+05	-.166E-01
2	.223E+00	.260E-01	.128E+01	.194E+05	-.142E-02
3	.225E+00	.261E-01	.125E+01	.192E+05	-.736E-04

Test Problem 4

➢ **Problem Statement:**

The figure below shows a portion of a piping system used to convey 750 gpm of ethyl alcohol. The system contains 180 ft of 12-nominal schedule 40 commercial steel pipe. All fittings are of the long radius type and are flanged. Calculate the pressure drop over this portion of the pipeline.



Liquid Properties (Ethyl alcohol, Appendix Table B.1):

$\rho = 0.787(62.4)$ lbm/ft^3 $\mu = 2.29 \times 10^{-5}$ lbf·s/ft^2

Condult Dimensions (12-nom sch 40:

$D = 0.9948$ ft, $A = 0.773$ ft^2

Relative roughness (commercial steel):

$\varepsilon = 0.00015$ ft, $V_1 = V_2$, $Z = 0$, $Z_2 = 8$ ft, $L = 180$ ft

Source:

William S. Janna. Design of Fluid Thermal Systems. PWS-Kent Publishing Co. Boston, MA, USA. Page 83.

➢ **Comments**

- The task is to calculate pressure.

- Input data in source are used.
- Remember to enter dynamic viscosity μ in lbf.h/ft^2 or lbm/ft.h.
- There are 2 minor loss types ($K_{45° \text{ elbow}}$, $K_{90° \text{ elbow}}$) with loss factors of 0.17 and 0.22 respectively. There are 2 of each.

➢ **Results**

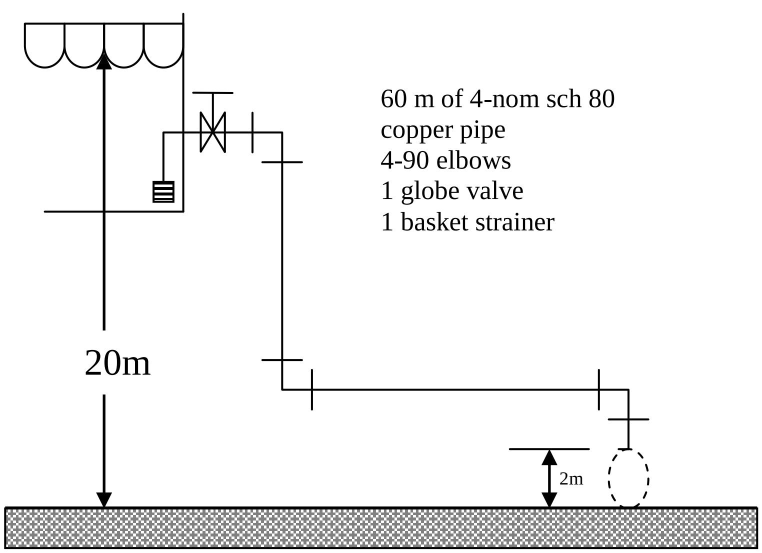
Variable	Janna	Janna	INSTED	Diff.
	British	SI	SI Units	
Δp	2.83 psi	19511 N/m^2	19490 N/m^2	< 1%
f	0.018	0.018	0.0177	< 1%
Re	1.43 x 10^5	1.43 x 10^5	1.43 x 10^5	< 1%

- Name of data file: JANNA.83

Test Problem 5

➢ **Problem Statement:**

A huge water reservoir is drained with a 4-nominal schedule 80 copper pipe. The piping system is shown below. The fittings are regular and threaded. Determine the volume flow rate through the system.



Liquid Properties (Water):

ρ = 1 000 kg/m^3, μ = 0.89 x 10^{-3} N•s/m^2

Conduit Dimensions (4-nom sch 80):

D = 9.718 cm, A = 74.17 cm^2

Relative roughness (copper pipe):

ε = 0.000 15 cm,
$V_1 = V_2 = 0$, Z_1 = 20 m, Z_2 = 2 m, L = 60 m

Source:
William S. Janna. Design of Fluid Thermal Systems. PWS-Kent Publishing Co. Boston, MA, USA. Page 85.

PIPE	Diameter (m)	Velocity (m/s)	Re	Friction factor	Minor loss
1	.303E+00	.655E+00	.143E+06	.177E-01	.780E+00

- **Comments**
  - The task is to calculate flow rate.
  - This is actually a **drainage** problem, no pump. Minor losses are included.
  - Input data in source are used.
  - No unit conversion is needed for this problem, other than conversion from cm to m.
  - There are 4 minor loss types - $K_{\text{basket strainer}}$, $K_{90° \text{ elbow}}$, $K_{\text{globe value}}$, K_{exit}, with respective loss factors 1.3, 1.4, 10, and 2.0. There are 1, 4, 1, and 1 counts for each type.

- **Results**

Variable	Janna	INSTED	Difference
velocity	3.61 m/s	3.66	< 1.4%
flow rate	0.0268 m^3/s	0.0271 m^3/s	1.1%
Re	3.93 x 10^5	4 x 10^5	1.8%
f	0.015	0.0139	7.3%

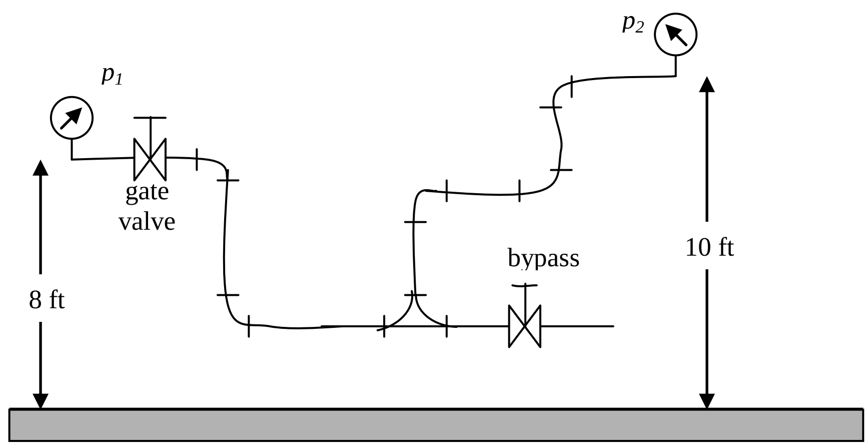
- Name of data file: JANNA.85

  Result screens are shown below.

Test Problem 6

- **Problem Statement:**

The figure below shows a piping system that consists of a line connected to two branches. When the bypass branch is closed off with its valve, the flow line is to deliver 0.3 ft^3/s of benzene with a pressure drop p_1-p_2 of 8.5 psi. Select a suitable size for the pipe if it is made of uncoated cast iron and has regular thread fittings. The length of pipe required is 700 ft. Due to cost considerations, it is desirable to use schedule 40 or schedule 80 pipe.



Solution: The control volume we select includes all the fluid in the pipe from the gage at section 1 to the gage at section 2, excluding the bypass.

Liquid Properties (Benzene):

ρ = 0.876(62.4)lbm/ft^3, μ = 1.26 x 10^{-5} lbf·s/ft^2

Relative roughness (uncoated cast iron pipe):

ε = 0.00085 ft; ε/D = 0.00085/D

Note: $V_1 = V_2$, Z_1 = 8 ft, Z_2 = 10 ft, L = 700 ft

Source:
William S. Janna. Design of Fluid Thermal Systems. PWS-Kent Publishing Co. Boston, MA, USA. Page 88.

- **Comments**
  - The task is to calculate pipe diameter for the case with minor losses.
  - Input data in source are used.
  - On-line unit conversion capability in INSTED is needed. Remember to enter dynamic viscosity μ in lbf.h/ft^2 or lbm/ft.h.
  - There are 3 types of minor losses - $K_{\text{gate valve}}$, $K_{90° \text{ elbow}}$, and $K_{\text{T-joint}}$, with respective loss factors of 0.15, 1.4, 1.9. The respective counts are 1, 5, and 1.

- **Results**

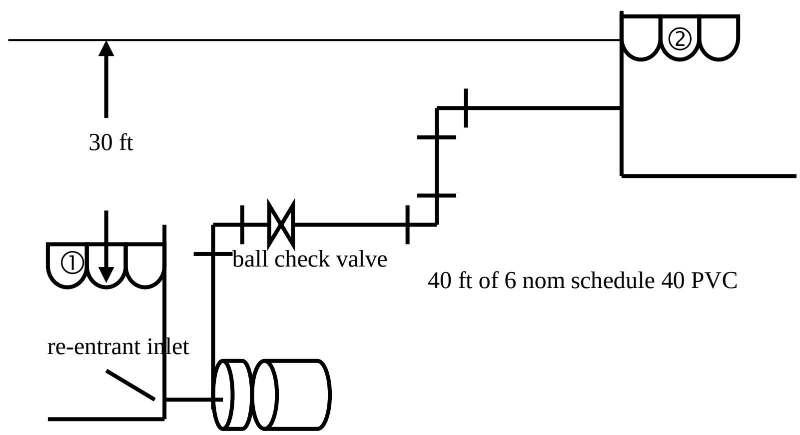
Variable	Janna	Janna	INSTED	Diff.
	British	SI	SI	
f	0.026	0.026	0.0268	<1%
Diameter	0.2957 ft	0.0901 m	0.0909	<1%

- Name of data file: JANNA.88

Test Problem 7

- **Problem Statement:**

The figure below shows a pipeline that conveys water to an elevated tank at a campsite. The elevated tank supplies water to people taking showers. The 40-ft long pipe contains 3 elbows and one ball check valve, and is made of 6-nominal schedule 40 PVC pipe. The pump must deliver 250 gpm. Use this figure to select a pump for the system. (Note Figure 5.4 of source is not used in INSTED®.)



Liquid Properties (Water)

ρ = 62.4 lbm/ft^3, μ = 1.9 x 10^{-5} lbf•s/ft^2

Conduit dimensions (6-nominal schedule 40)

ID = 0.5054 ft, *A* = 0.2006 ft^2

Property Evaluation

$p_1 = p_2 = p_{atm} = 0$, $V_1=V_2$, $z_1 = 0$, $z_2 = 30$ ft

Q = 250 gal/min = 0.555 ft^3/s, V = Q/A = 0.555/0.2006 = 2.76 ft/s.

Minor Losses (90° elbows, re-entrant inlet, ball check valve, exit)

$$\Sigma \quad K = 3K_{90°\ elbow} + K_{re\text{-}entrant\ inlet} + K_{ball\ check\ valve} + K_{exit}$$

$$\Sigma \ K = 3(0.31) + 1.0 + 70 + 1.0 = 72.9$$

Source:
William S. Janna. Design of Fluid Thermal Systems. PWS-Kent Publishing Co. Boston, MA, USA. Page 168.

- **Comments**
  - The task is to calculate pipe diameter for the case with minor losses.
  - Input data in source are used.
  - On-line unit conversion capability in INSTED is needed. Remember to enter the dynamic viscosity μ in lbf.h/ft^2 or lbm/ft.h.
  - There are 4 minor loss types - $K_{90°\ elbow}$, $K_{re\text{-}entrant\ inlet}$, $K_{ball\ check\ valve}$, and K_{exit}, with respective loss factors of 0.31, 1.0, 70, and 1.0 and counts 3, 1, 1, and 1.
  - Result screens are shown below.

TRIAL	**DIAMETER**	**FRICTION**	**VELOCITY**	**REYNOLDS**	**F DIFF**
1	.696E-01	.285E-01	.223E+01	.225E+06	-.205E-01
2	.898E-01	.269E-01	.134E+01	.175E+06	.164E-02
3	.887E-01	.269E-01	.137E+01	.177E+06	-.697E-04
CASE WITH NO MINOR LOSS HAS BEEN COMPLETED PLEASE HIT RETURN KEY FOR THE CASE WITH MINOR LOSS					
TRIAL	**DIAMETER**	**FRICTION**	**VELOCITY**	**REYNOLDS**	**F DIFF**
1	.917E-01	.267E-01	.129E+01	.171E+06	.194E-03
2	.909E-01	.268E-01	.131E+01	.173E+06	-.512E-04

- **Results**

Variable	**Janna**	**Janna**	**INSTED**	**Diff.**
	British Units	SI Units	SI Units	
Power	2.44 hp	1819.5 W	1831	< 1%

- Name of data file: JANNA.168