TEXAS TECH UNIVERSITY

DEPARTMENT OF CIVIL, ENVRONMENTAL, AND CONSTRUCTION ENGINEERING

Lab Report #5: Minor Losses in a Pipe Network

[redacted]

Date of Experiment: [redacted]

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THEORY

Pipe networks are full of fittings. Losses due to the fitting of the pipe, usually either a pipe bend or sudden contractions/expansions, are called minor losses. The pressure losses due to these minor losses are defined as the pressure difference between upstream and downstream measurements of the system.

When fluid flows through a 90° bend, the amount of loss experienced will depend on the ratio *R/D*. In this ratio, *R* is the radius of curvature of the bend, and *D* is the diameter of the pipe. The smaller the ratio, the lower the minor loss coefficient K is.

Table 1: Theoretical K value categories

Theoretical K Values		
Miter	Elbow	Large Radius
1.4 to 1.6	1.1 to 1.4	0.20 to 0.80

If the pipe suddenly expands, the flow splits and forms eddies, which divert the flow and reduce the head. If the pipe suddenly contracts, vortices and eddies form, interrupting the flow and reducing the head. Similar losses occur at smaller scales in more graduate expansions and contractions, such as the one in **Figure 1**.

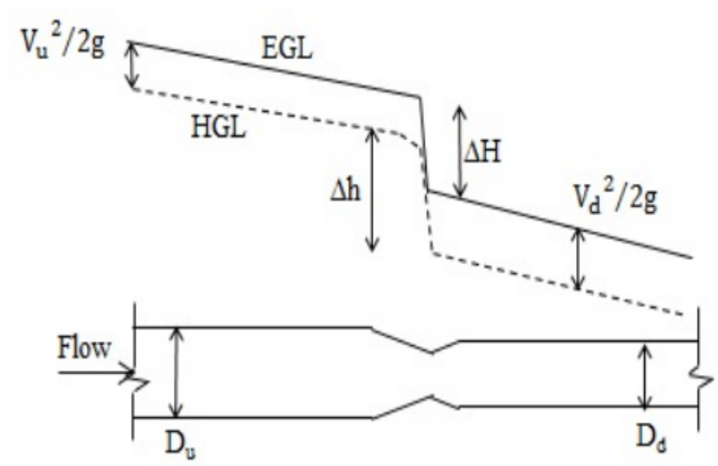


Figure 1. Example of loss at a pipe fitting. This pipe fitting has a unique effect on the head of the pipe flowing through it.

For the fitting in **Figure 1**, the total head loss is as follows:

$$\Delta H = \Delta h + \frac{V_u^2 - V_d^2}{2g} \tag{1}$$

$\Delta H = total\ head\ loss$
$\Delta h = head\ loss\ between\ two\ points$
$V = velocity\ of\ fluid$
$g = acceleration\ due\ to\ gravity$

The loss coefficient, *K*, is defined as either:

$$K = \Delta H \Big/ \left(\frac{V_d^2}{2g}\right) \tag{2}$$

Or:

$$K = \Delta H \Big/ \left(\frac{V_u^2}{2g}\right) \tag{3}$$

In our experiment, the pipe fittings have constant diameters. This means that $V_u = V_d$. To evaluate the velocity head at the sudden expansion, we measured the upstream velocity; at the sudden contraction, we measured the downstream velocity.

Below is a table of the equations needed for the pipe fittings encountered during our experiment.

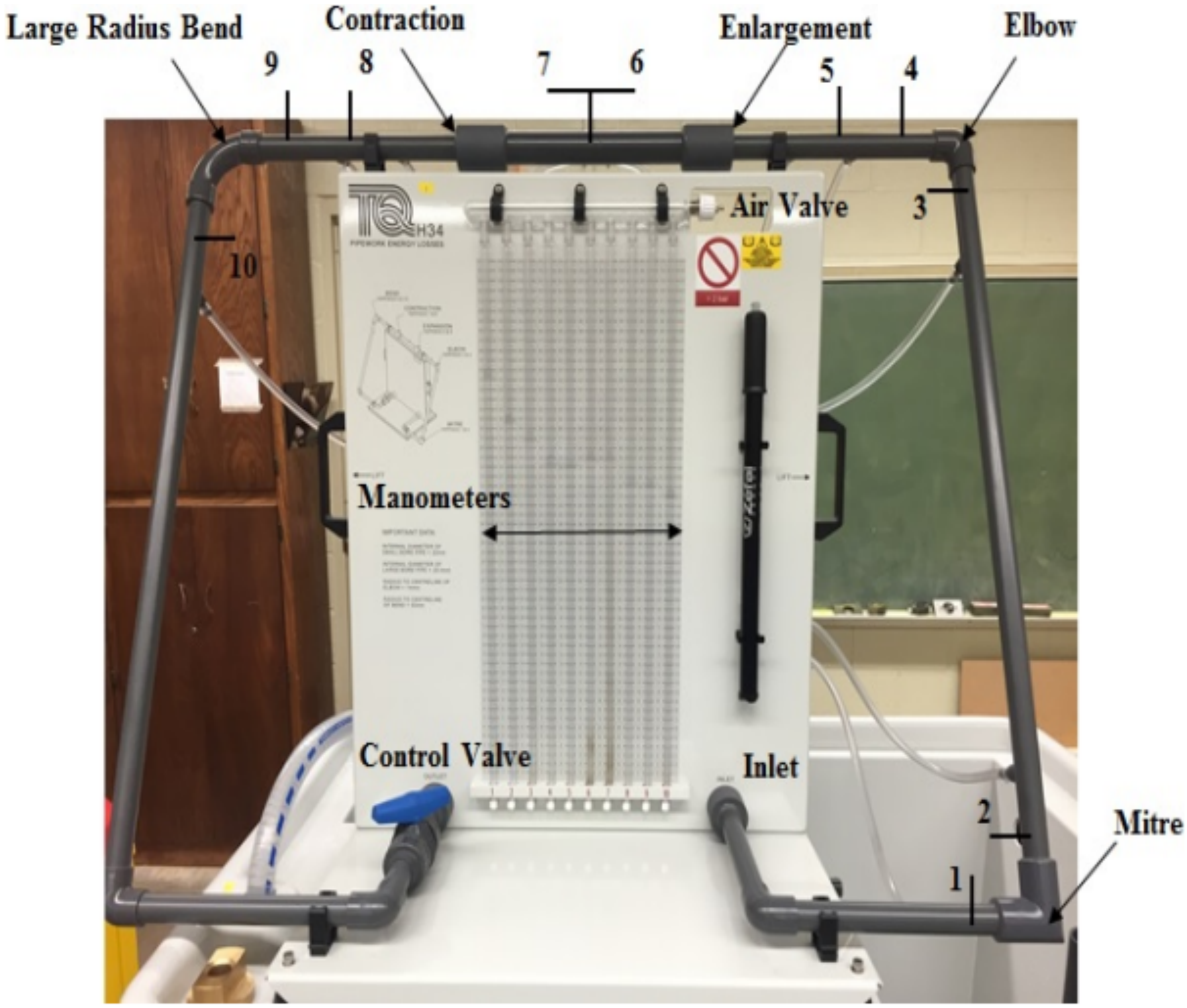
Table 2: Equations for experimental fittings

Equation Description	Equation	#
K-value for miter, elbow, bend	$K = \Delta H \Big/ \left(\frac{V_1^2}{2g}\right)$	4
Head loss for sudden expansion	$\Delta H = \Delta h + \frac{V_1^2 - V_2^2}{2g}$	5
K-value for sudden expansion	$K = \left(1 - \frac{A_c}{A_d}\right)^2$	6
K-value for sudden expansion (alternative, varies from 0 to 1.00)	$K = \Delta H \Big/ \left(\frac{V_1^2}{2g}\right)$	7
Head loss for sudden contraction	$\Delta H = \Delta h + \frac{V_2^2 - V_1^2}{2g}$	8
K-value for sudden contraction	$K = \left(\frac{A_d}{A_c} - 1\right)^2$	9
K-value for sudden contraction (alternative, varies from 0 to 0.44)	$K = \Delta H \Big/ \left(\frac{V_2^2}{2g}\right)$	10

APPARATUS (RD)

<u>Figure 2:</u> <u>Apparatus used in experiment 5</u>

Below is a labeled photo of the apparatus used in the Minor Losses in a Pipe Network experiment. The labels not only describe the parts but help label the certain points in the pipe and their respective manometers.



EXPERIMENT PARAMETERS (RD)

1. **Loss coefficient (unitless)**

This is a unitless coefficient that correlates to the shape of the pipe. The corresponding formulas are listed in the theory section.

2. **Measured head loss between two points (ft)**

This is the difference of head losses between certain points in the piping. This is found from the manometer levels (listed as the tube height readings below).

3. **Velocity (ft/s)**

The velocities calculated in the smaller and larger bore pipe and at u/s and d/s are recorded in feet per second.

4. **Cross-sectional area (ft/s and ft^2)**

The cross-sectional are at u/s and d/s are recorded in feet per second. The cross-sectional area at vena contracta.

5. **Gravity (ft/s^2)**

This is the standard gravitational force experienced on Earth. It is used in several calculations.

6. **Total Head Loss (ft)**

The sum of the head losses for the enlargement and contraction portions of the pipe network is what this lab calculated,

7. **Bore diameter (ft)**

The bore diameters are .072 feet and .093 feet. They are represented by D_1 and D_2 in formulas.

8. **Volume (L)**

A beaker was used to collect water from the outflow of the apparatus to get the volume that had flowed out in a certain amount of time.

9. **Time (s)**

An iPhone timer was used to have the students let the outflow pipe fill a beaker for a certain amount of time.

10. **Temperature (°C)**

A thermometer was used to measure the temperature of the water used in the experiment.

11. **Flow Rate (L/s and ft^3/s)**

The flow rate is calculated from the volume of water that has flowed out of the Minor Losses in a Pipe Network apparatus in a certain amount of time.

12. **Density (lb/ft^3)**

The density of water based on the temperature recorded during the lab is used in a few calculations and is recorded in pounds per foot cubed.

13. **Tube Height reading (mm)**

These are the manometer levels on the apparatus that are linked to different parts of the piping to get the head loss experienced in certain segments.

RESULTS (RD)

Table 3: Minor Losses in a Pipe Network Recorded Data

The table below shows the recorded data from the experiment. The tube height readings, flow rate, and the measurements used to find flow rate are shown below.

Read-ing #	Vol. of Water (L)	Time (s)	Flow Rate	Tube Height Reading (mm)									
				1	2	3	4	5	6	7	8	9	10
Init.	-	-	-	428	428	428	428	428	428	428	428	428	428
1	.810	5	.162	413	397	389	378	376	380	380	370	370	365
2	1.630	5	.326	347	291	260	225	220	230	231	195	194	174
3	1.72	5	.344	322	263	230	190	187	198	199	160	153	135
4	1.82	5	.364	291	215	180	136	131	144	145	100	97	74
5	1.9	5	.38	270	192	156	111	108	120	120	73	70	49

Table 4: Minor Losses in a Pipe Network Calculated Data

The table below depicts the calculated values from the experiment.

Flow Rate (ft^3/s)	V_1 (ft/s)	(V_1)^2 /2g (ft) (x10^4)	V_2 (ft/s)	(V_2)^2 /2g (ft) (x10^4)	Measured Head Loss Δh (ft)					Total Head Loss ΔH (ft)	
					1-2	3-4	5-6	7-8	9-10	Enlargement	Contraction
.006	.083	1.08	.065	.646	.052	.036	-.013	1.25	.016	.006	.006
.012	.167	4.31	.129	2.59	.184	.115	-.033	.033	.066	.012	.012
.012	.167	4.31	.129	2.59	.194	.131	-.036	.128	.059	.012	.012
.013	.181	5.06	.140	3.03	.249	.144	-.043	.147	.075	.013	.013
.013	.181	5.06	.140	3.03	.256	.148	.391	.154	.069	.013	.013

DISCUSSION

EXPERIMENT PURPOSE

The purpose of this experiment is to determine the different behaviors that the fluids interact with dealing with the different bends that a pipe might have to form to help efficiently transport a fluid. From the results we see that each of the fittings results in different flowrates where we can use to find the head loss between these fittings and compare how efficient each fitting is. From the results we can see for a bend that the large radius bend would be the best choice if we want to reduce our head loss.

REPORT QUESTIONS

1. Explain the calculated loss coefficient values for different fittings. How do they differ?

The coefficient values for each fitting are different since each fitting results in different ways for water to flow. From the results we can see that the smaller loss coefficients will have an improved flow rate and less head loss compared to the higher coefficients. The large radius bend had lower K compared to the mitre and elbow. The loss coefficient between the the mitre and elbow is similar due to the size but the small arc that the elbow provides the advantage. The results prove that an arc would prove more useful in terms of head loss and to increase the efficiency than the radius of that needs to increase.

2. Compare the calculated loss coefficient values with the theoretical values. How do they differ?

The calculated K values determined to be in the range to the said theoretical values.

3. Which fitting is best to design a pipe system?

From the results, a large radius bend would prove to be the best use when the factor is achieving a low loss coefficient / head loss. When size and space is an issue it might not be suitable for a large bend to be placed, instead that where an elbow or mitre could be used but with the sacrifice of a higher head loss.

4. Describe the characteristics of flow through bends where loss coefficient K is a function of the geometric ratio R/D.

Water flowing will differ to the ratio of curvature to the diameter of the pipe. Increasing the coefficient starting at 1 would eventually lead to a better loss coefficient until the efficient K is found, after that increasing the ratio would lead back to higher head loss. A ratio around 2-3 would lead to a low loss coefficient and increasing the values will see an increase in K. A ratio from 0-2 would have a better K compared to anything past 3 but would not be the most efficient flow rate.

PRACTICAL APPLICATION

A real life application of this experiment would be the use of pipes when transporting water. You will find in most buildings / houses in the states would have running water. This is achieved by spanning pipelines to transport water to houses. Different uses of piping is subject to change when needing to be much smaller to fit into a structure. To maintain good pressure for water the use of different fittings is important. No one wants to use a sink or shower with low pressure which would be affected by the use of improper fittings. The effect caused by various changes in pipe shape should be taken into consideration when designing the pump and pipe systems to transport water to areas where it will be used. Engineers can know how much higher the input flow of water needs to be in order for the output to have a desirable amount of pressure. This can be done by tapering fittings, decreasing pipe diameter nearer to the output valves, and increasing the input flow rate, just to name a few examples. Of course, raising the elevation of the input end with relation to the output end would help a lot too, but that isn’t always an option. It's best to try and use our understanding of fittings to work in our favor.

DATA APPENDIX

CE3105 Mechanics of Fluids Laboratory Department of Civil Engineering

Texas Tech University

Experiment: Pipe[redacted]

Date of Experime[redacted]

Experimental Data:

Temperature of water, T= _________ °Celsius Water density, ρ = (lb/ft3) Gravity, g= 32.2 (ft/s2

	Reading Number	Volume of Water (L)	Time (s)	Flow Rate V/T	Tube Height Reading (mm)									
					1	2	3	4	5	6	7	8	9	10
initial	1	None			427	427	428	428	—					— all even
1	2	.810	5		413	397	389	378	376	380	380	370	370	365
2	3	1.630	5		347	291	260	225	220	230	231	195	191	174
3	4	[redacted]	5		322	263	230	190	187	198	199	160	153	135
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	145	100	97	74
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	120	73	70	47

CE3105 Mechanics of Fluids Laboratory Department of Civil Engineering

Texas Tech Univ[redacted]

Experiment: Pipe[redacted]

Date of Experime[redacted]

Experimental Data:

Temperature of water, T= 20 °Celsius Water density, ρ = (lb/ft3) Gravity, g= 32.2 (ft/s2

	Reading Number	Volume of Water (L)	Time (s)	Flow Rate L/s	Tube Height Reading (mm)									
					1	2	3	4	5	6	7	8	9	10
initial	1	no flow	no flow	0	427	427	428	428	428	428	428	428	428	428
1	2	.870	5	0.174	413	397	389	88	376	380	380	370	370	365
2	3	1.630	5	0.326	347	291	260	225	220	230	231	195	191	174
3	[redacted]										99	160	153	135
4	[redacted]										45	100	97	74
5	[redacted]										20	73	70	49

Instr[redacted]

CE3105 Mechanics of Fluids Laboratory Department of Civil Engineering

Texas Tech University

Experiment: [redacted]

Date of Expe[redacted]

Experimental Data:

Temperature of water, T= 20 ◦Celsius Water density, ρ = (lb/ft3) Gravity, g= 32.2 (ft/s2

Initial Read
427 427 428
426 426 428

Reading Number	Volume of Water (L)	Time (s)	Flow Rate	Tube Height Reading (mm) 1	2	3	4	5	6	7	8	9	10
1	.870	5		427	397	389	376	376	380	380	370	370	365
2	1.63	5		347	291	260	225	220	230	231	195	191	174
3	1.72	5		322	263	230	190	187	198	199	160	153	135
[redacted]	[redacted]	[redacted]		291	215	180	136	131	144	145	100	97	74
[redacted]										129	82	80	56
										120	73	70	49

ERROR CALCULATIONS

We only ran one trial for each of the different flow rates through the apparatus. Sources of error might arise in the accuracy of timing the flow rate. Since each volume was recorded with the same time our room for error minimizes compared to reaching a specific volume of a high flow rate and recording the time afterwards.

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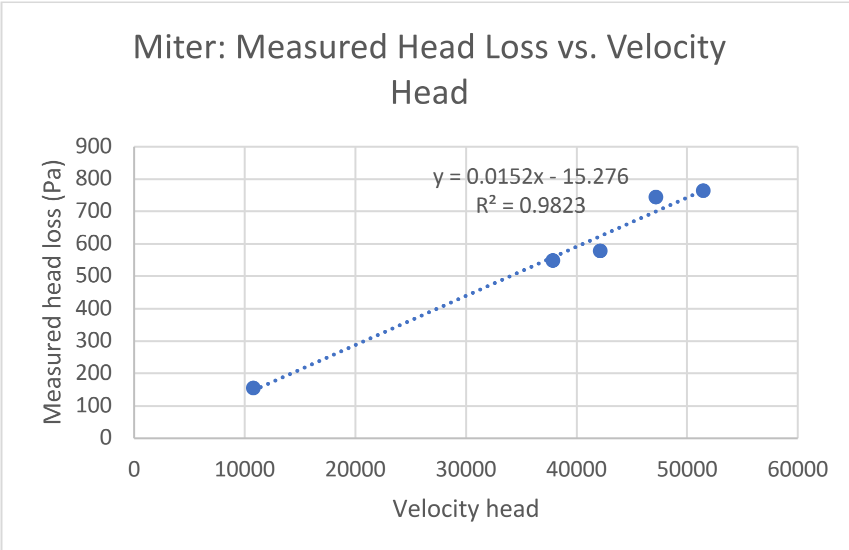
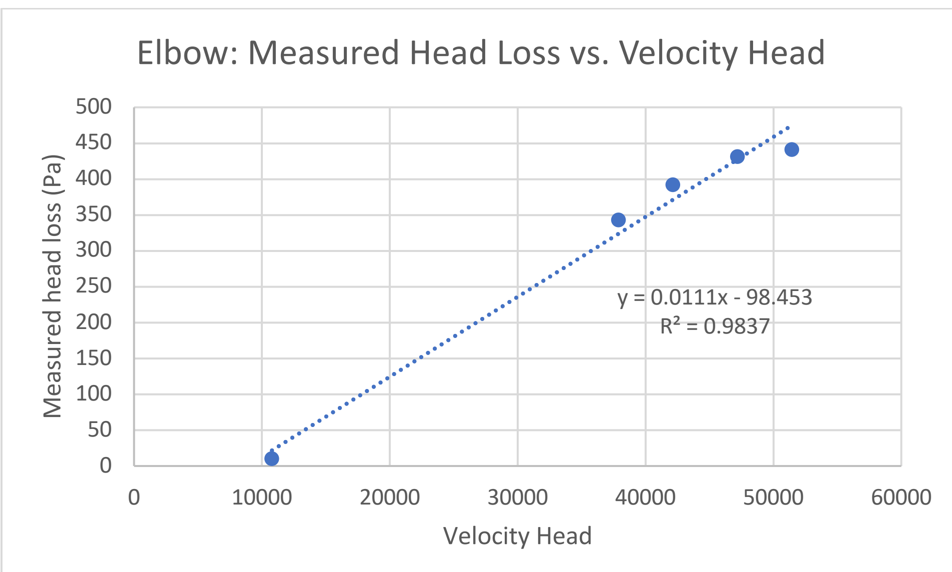
SAMPLE CALCULATIONS

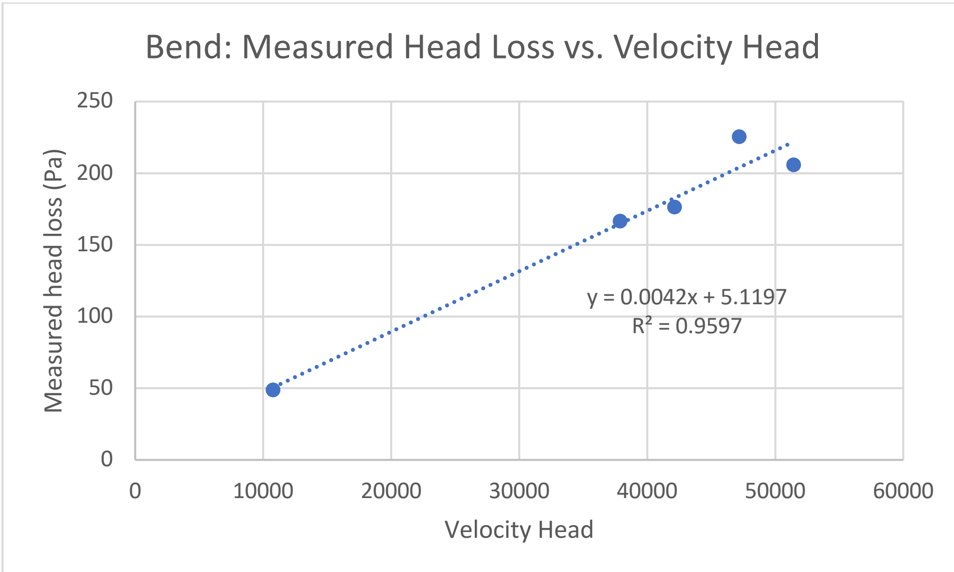
MITER PLOT



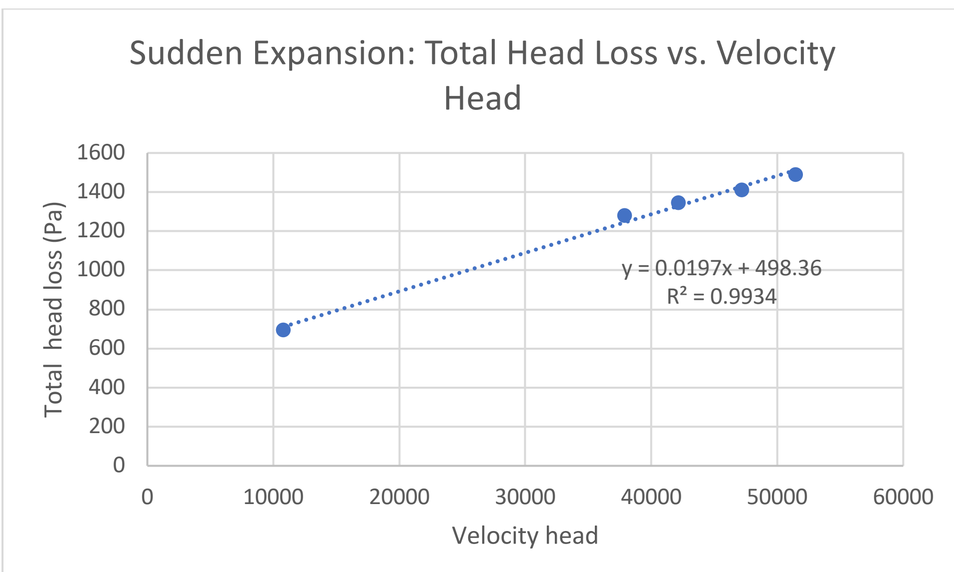
ELBOW PLOT



BEND PLOT



SUDDEN EXPANSION PLOT



SUDDEN CONTRACTION PLOT