ENGG *2230

Fluid Mechanics: Lab 4

Laboratory #4 – Minor Losses

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Section #3 - Group A1

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Introduction

Deformities and imperfection in a pipe can lead to minor losses of fluid flow in a pipe (Joy 2018). However, these losses are significantly small and do not impact the system as a whole, but it is imperative to account for them to avoid changes in a flow. They can also significantly impact the overall operation of the system, therefore it is important to notice such losses. These losses can occur due to changes in geometry and result from changes in flow and direction of the fluid (Joy 2018). This experiment will determine the minor energy losses for four geometries; sudden expansion, a 90° reducing bend, a venturi meter and an orifice plate (Joy 2018).

Cumulative minor losses in pipes can lead to major errors in flow calculations (Joy 2018). For example, in a plumbing system at home, there are numerous bends and various geometries to fit the structural needs to the house. There are bound to be losses of flow rate due to friction in the pipe boundaries and also improper geometries. This will lead to a decreased outflow, therefore it is imperative to account for the minor losses in order to mitigate them.

Description of Apparatus

The hydraulic bench acts as a water supply which attaches to the apparatus as observed in figure 1. The flow apparatus was connected to manometer tubing, discharge valves, water outlet and supply, rotameter, orifice plate and venturi meter. Other equipment used was a set of 2 kilogram weights and a stopwatch to measure the flow of water at different rotameter values and an air pump to obtain the desired initial pressure reading.

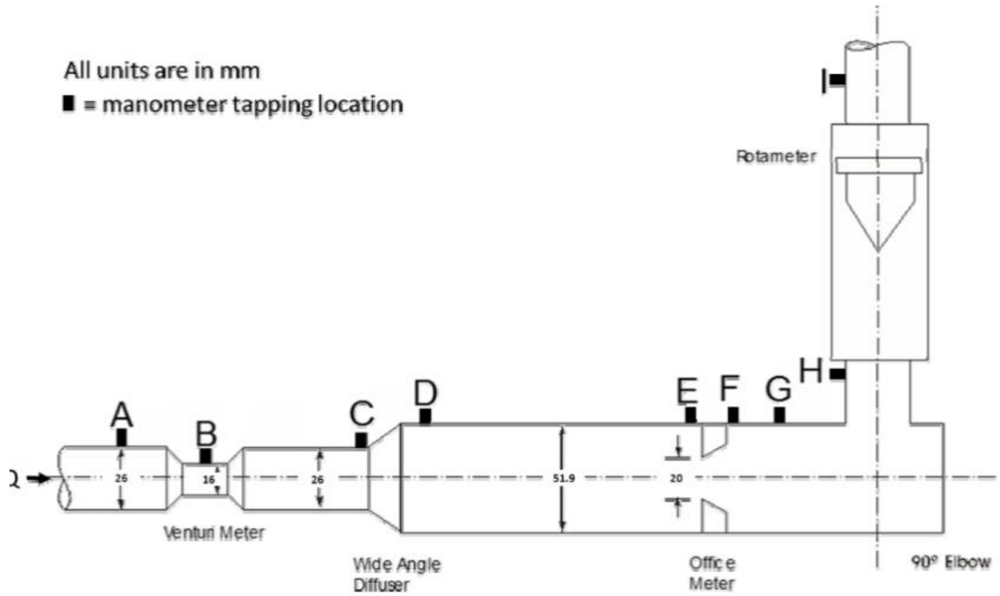


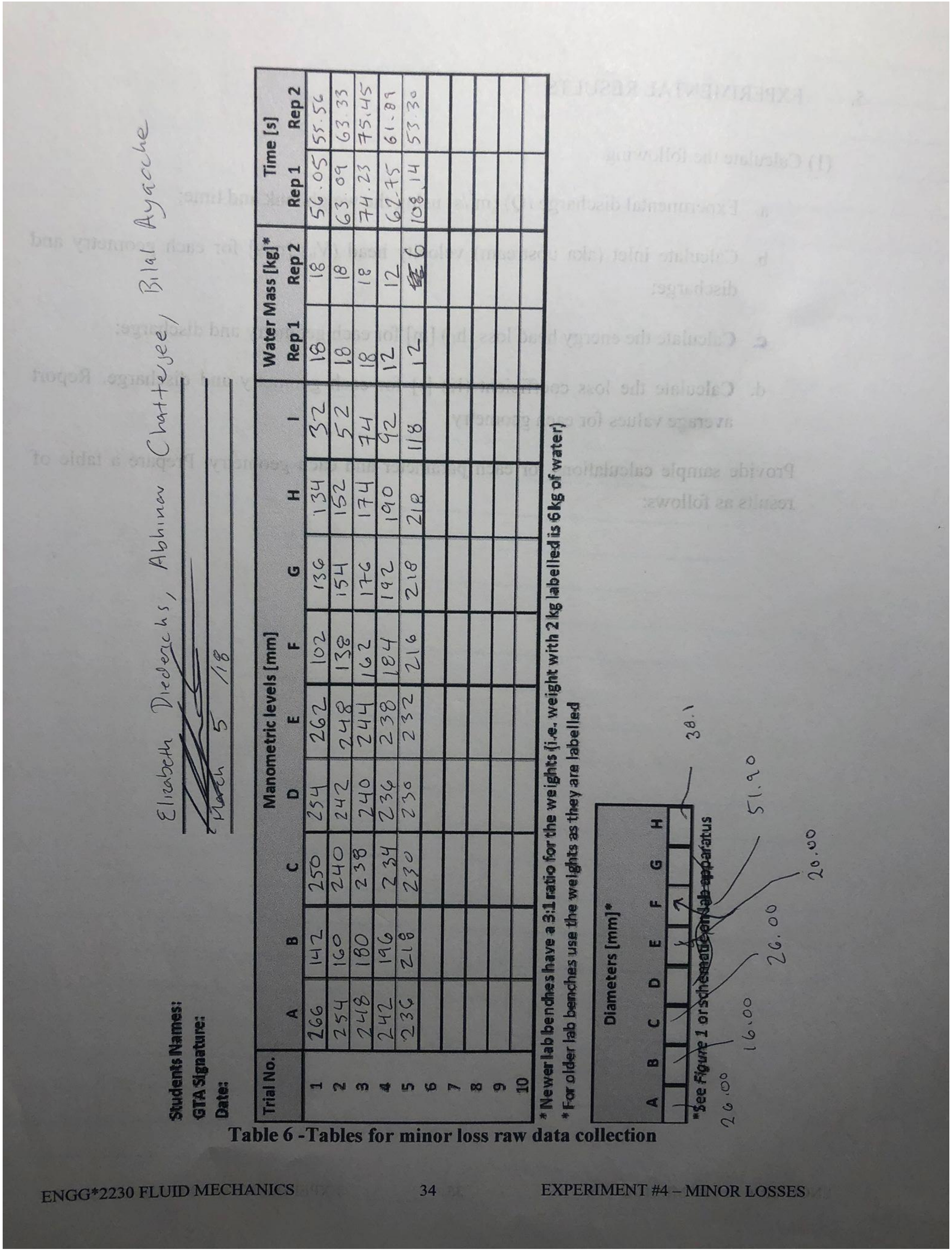
Figure 1: Flow measuring apparatus (Joy 2018)

Methodology

The flow apparatus, shown above in figure 1, was connected to the hydraulic bench. The purpose was to measure the flow of water using different manometer levels as it flow through the different geometries.

Water enters through the Venturi meter along the gradual diverging section (Joy 2018). After the flow moved through the rapidly diverging section, which is a wide-angle diffuser, it reaches the orifice meter (Joy 2018). Eventually it travels through a settling length and 90° bend to enter the rotameter (Joy 2018). The rotameter is mounted between two pressure tapped flanges. Manometer readings on either side of each geometry are taken after adjusting the rotameter in equal divisions. Initially, an air pump is used to settle the pressure to a desired reading and to remove any air bubbles. To obtain the flow readings, when the counter weight was observed to reach the bar, blocking it from emptying, the weights were placed to counter the flow of the tank. The stop watch was started instantly as the weights were placed to counter the flow. The amount of time taken for the tank to fill up was recorded. This procedure was performed twice for each trial.

Results



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Date: March 5 /18

Trial No.	Manometric levels [mm] A	B	C	D	E	F	G	H	I	Water Mass [kg]* Rep 1	Rep 2	Time [s] Rep 1	Rep 2
1	266	142	250	254	262	102	136	134	32	18	18	56.05	55.56
2	254	160	240	242	248	138	154	152	52	18	18	63.09	63.33
3	248	180	238	240	244	162	176	174	74	18	18	74.23	75.45
4	242	196	234	236	238	184	192	190	92	12	12	62.75	61.89
5	236	218	230	230	232	216	218	218	118	12	6	108.14	53.30
6													
7													
8													
9													
10													

* Newer lab benches have a 3:1 ratio for the weights (i.e. weight with 2 kg labelled is 6 kg of water)

* For older lab benches use the weights as they are labelled

Diameters [mm]* A	B	C	D	E	F	G	H

*See Figure 1 or schematic on lab apparatus

26.00

16.00

26.00

20.00

51.90

38.1

Table 6 - Tables for minor loss raw data collection

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The raw data of manometric level heights, time, and water mass was collected. 6 points came from this experiment and 6 points were from Lab 1. This data was used to calculate discharge and inlet velocity head, energy head loss, and the loss coefficient for each geometry. These values are shown in Table 1 and 2.

Table 1 – Calculated results of inlet velocity and energy head loss

Trial No.	Q [m^3/s]	Inlet Velocity Head (V_u) [m/s]				Energy Head Loss (h_f) [m]			
		Ve	De	Or	El	Ve	De	Or	El
1	0.000323	0.608	0.608	0.152	0.152	0.0160	0.0136	0.107	0.079
2	0.000285	0.536	0.536	0.135	0.135	0.0140	0.0117	0.069	0.080
3	0.000241	0.453	0.453	0.114	0.114	0.0100	0.0078	0.053	0.080
4	0.000193	0.363	0.363	0.091	0.091	0.0080	0.0043	0.035	0.081
5	0.000112	0.211	0.211	0.053	0.053	0.0060	0.0021	0.010	0.080
6	0.000354	0.666	0.666	0.167	0.167	0.0230	0.0162	0.137	0.081
7	0.000300	0.565	0.565	0.142	0.142	0.0180	0.0132	0.087	0.082
8	0.000284	0.536	0.536	0.134	0.134	0.0140	0.0117	0.077	0.080
9	0.000218	0.410	0.410	0.103	0.103	0.0120	0.0060	0.048	0.081
10	0.000138	0.259	0.259	0.065	0.065	0.0060	0.0012	0.020	0.079

Table 2 – Calculated results of loss coefficient

Trial No.	Loss Coefficient (K)			
	Ve	De	Or	El
1	0.851	0.724	90.690	66.763
2	0.955	0.801	74.767	86.351
3	0.956	0.746	80.112	122.016
4	1.193	0.639	83.530	191.741
5	2.656	0.937	68.120	559.894
6	1.017	0.716	96.014	56.508
7	1.108	0.814	84.673	79.660
8	0.957	0.800	83.701	86.539
9	1.402	0.703	89.220	149.675
10	1.752	0.353	94.728	368.424
Average	1.285	0.723	84.556	176.757

The energy head loss was plotted as a function of the inlet velocity head in figure 2.

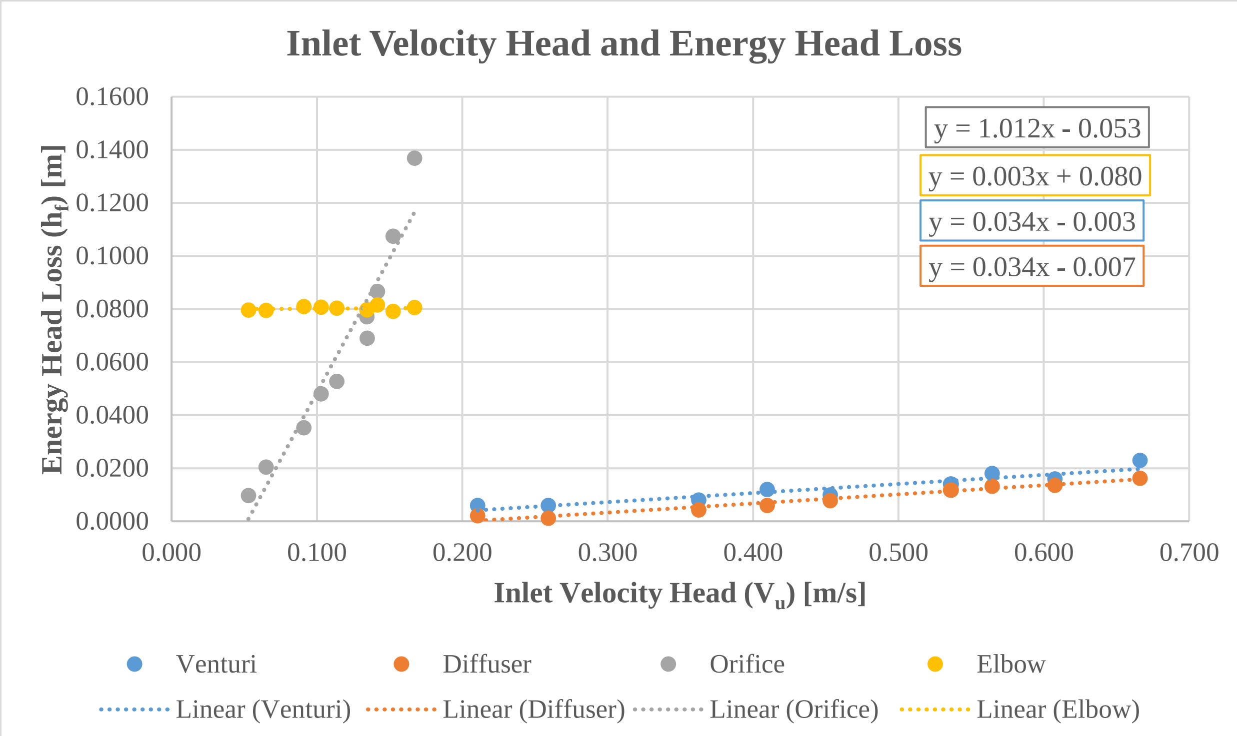

Figure 2 – Graph of inlet velocity head and energy head loss

Sample Calculations

Discharge

$$Q = M_W \left(\frac{1\ L}{1\ kg}\right)\left(\frac{1\ m^3}{1000\ L}\right)\left(\frac{1}{\frac{t_1 + t_2}{2}}\right)$$

$$Q = 18\ kg\ (\frac{1\ L}{1\ kg})(\frac{1\ m^3}{1000\ L})(\frac{1}{\frac{56.05\ s + 55.65\ s}{2}})$$

$$Q = 0.000323\ m^3/s$$

Inlet Velocity

$$D_A = 0.026\ m$$

$$V_{u_{venturi}} = \frac{Q}{A}$$

$$V_{u_{venturi}} = \frac{0.000323\ m^3/s}{\frac{\pi}{4}(0.026\ m)^2}$$

$$V_{u_{venturi}} = 0.608\ m/s$$

$$*\ for\ other\ geometries, use\ associated\ diameters$$

$$Diffuser: D_C = 0.026\ m$$

$$Orifice: D_E = 0.0519\ m$$

$$Elbow: D_G = 0.0519\ m$$

Energy Head Loss

$$h_f = z_u - z_d + \frac{{V_u}^2 - {V_d}^2}{2g} + \frac{P_u - P_d}{\gamma}$$

$$h_f = z_u - z_d + \frac{{V_u}^2 - {V_d}^2}{2g} + h_u - h_d$$

$$where\ h_u\ and\ h_d\ refer\ to\ manometric\ levels$$

a) Venturi

$$V_1 = V_2$$

$$Z_1 = Z_2$$

$$h_f = h_A - h_C$$

$$h_f = 0.266\ m - 0.250\ m$$

$$h_f = 0.016\ m$$

b) Diffuser

$$Z_C = Z_D$$

$$D_D = 0.0519\ m$$

$$h_f = \frac{{V_C}^2 - {V_D}^2}{2g} + h_C - h_D$$

$$h_f = \frac{\left(0.608\,\frac{m}{s}\right)^2 - \left(\frac{0.000323\,\frac{m^3}{s}}{\frac{\pi}{4}(0.0519\,m)^2}\right)^2}{2\left(9.81\,\frac{m}{s^2}\right)} + 0.250\,m - 0.254\,m$$

$$h_f = 0.0136\,m$$

c) Orifice

$$Z_E = Z_F$$

$$D_F = 0.020\,m$$

$$h_f = \frac{{V_E}^2 - {V_F}^2}{2g} + h_E - h_F$$

$$h_f = \frac{\left(0.152\,\frac{m}{s}\right)^2 - \left(\frac{0.000323\,\frac{m^3}{s}}{\frac{\pi}{4}(0.020\,m)^2}\right)^2}{2\left(9.81\,\frac{m}{s^2}\right)} + 0.262\,m - 0.102\,m$$

$$h_f = 0.107\,m$$

d) Elbow

$$D_H = 0.0381\,m$$

$$\Delta h = 0.08\,m$$

$$h_f = z_G - z_H + \frac{{V_G}^2 - {V_H}^2}{2g} + h_G - h_H$$

$$h_f = 0.08\,m + \frac{\left(0.152\,\frac{m}{s}\right)^2 - \left(\frac{0.000323\,\frac{m^3}{s}}{\frac{\pi}{4}(0.0381\,m)^2}\right)^2}{2\left(9.81\,\frac{m}{s^2}\right)} + 0.136\,m - 0.134\,m$$

$$h_f = 0.0791\,m$$

Loss Coefficient

$$K = \frac{h_L(2g)}{{V_u}^2}$$

$$K = \frac{0.016\,m\,(2)\left(9.81\,\frac{m}{s^2}\right)}{\left(0.608\,\frac{m}{s}\right)^2}$$

$$K = 0.852$$

Discussion

For examining the loss coefficients, the experimental values will be compared with the published K values, along with their experimental errors in the Table 3.

Table 3 – Comparison of theoretical and experimental loss coefficients (White 2016)

Geometry	Published K values	Experimental K values	Percent error (%)
Venturi meter	0.20	1.285	543
Diffuser	0.32	0.723	126
Orifice Plate	2.20	84.556	3744
90^o elbow	0.95	176.757	18506

Sample Calculation

Percent Error

$$\%\,error = \frac{\left|K_{theoretical} - K_{experimental}\right|}{K_{theoretical}}(100\%)$$

$$\%\,error = \frac{|0.20 - 1.285|}{0.20}(100\%)$$

$$\%\,error = 543\ \%$$

The K values were obtained by taking the average of the 10 trails for the different geometries. The experimental loss coefficients for the Venturi meter, Diffuser, Orifice plate and 90° Elbow had experimental errors of 543 %, 126 %, 3744 % and 18506 % respectively. This suggests that the experimental loss coefficients are far greater than the published values. This indicates that this experiment encountered a greater loss of energy than hypothesized.

Our calculated results for the experimental loss coefficients would suggest that losses are far greater than the published values. However, K values often vary with upstream velocity (Joy 2018). This could suggest that our values, as dramatically different as some may be could have been measured at far different upstream velocities from the published K values.

We see an increase in head loss for the orifice geometry as the inlet velocity and flow rate increase. The loss coefficient (K) decreases as the inlet velocity head increases and averages at a K value of 84.556.

For the Venturi meter, a less dramatic leap in energy head loss is seen. As the inlet velocity, and the flow rate increase, the head loss increases from the value of 0.006 m to 0.016 m. The loss coefficient decreases from a value of 1.752 to 0.851 as the inlet velocity head increases from 0.259 m/s to 0.608 m/s. The average K value is 1.285.

On the other hand, the diffuser meter's energy head loss also leaps less dramatic. As the Inlet Velocity, and the flow rate increase, the head loss increases from the value of 0.0012 m to 0.0136m. The loss coefficient averages at a value of 0.723.

Finally, for the 90° elbow, the Energy head loss remains almost constant with a fluctuation of ± 0.1 m as the inlet velocity head and flow rate increases. The energy head loss averages at a value of 0.079. As the inlet velocity increases from 0.065 m/s to 0.152 m/s, the loss coefficient drastically decrease from a value of 368.423 to 66.763 and averages at 176.757 over the 10 trials. The elbow also incurred the greatest amount of losses, which can be understood qualitatively. The fluid travelling horizontally encounters a wall and is diverted upwards against gravity, leading to an imminent loss in energy.

These values similarly correspond with the dramatic differences in calculated verses experimental values, showing that the increase in velocity likely influences the K values for these specific velocities. It is notable that the K values increase as the inlet velocity decreases. Therefore, there is a far greater chance of energy loss at lower velocities.

Head losses that occurs due to friction are not accounted for based on the assumption that all head losses are due to minor losses. Human error must be taken into consideration as the accuracy of the apparatus and the reading can drastically affect the results. Measurements could be off in timings and manometer readings throughout the experiment. It was difficult to take accurate readings of the lower meniscus on the manometer due to the fluctuations of the fluid. The fluctuations could also account for some of the discrepancies in loss coefficients.

Conclusion

It is evident from the experimental results that changes in geometry result in drastic losses of energy from a fluid. The experimental errors were enormous when compared to published K values, leading to the conclusion that the loss coefficient is much higher in this experiment. It is also notable that the K coefficient will vary with upstream velocity, therefore it is possible that the loss coefficients could be different in various areas of the apparatus.

According to the lab results, the greatest loss in energy occurred in the 90° elbow with an average K value of 176, whilst the lowest energy loss occurred in the diffuser with an average of 0.72. Therefore, we can conclude that minor losses can alter the expected results of a system and require proper understanding. It is very important to account for every minor loss within a system in order to accurately depict the flow and overall performance of a system. lThis is especially important in smaller systems where the losses have greater effect, such as in the plumbing in houses.

Works Cited

Joy, D. M. (2018). Fluid mechanics laboratory manual. Guelph, ON: University of Guelph, School of Engineering.

White, Frank M. (2016). Fluid Mechanics. University of Rhode Island. Eighth edition pg. 396-422, Fig 6.21, 6.22, Eq. 6.77, 6.78, 6.79