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# Major and Minor Losses in Various Flow Apparatus's

## Abstract:

An analysis of the Technovate fluid circuit system and the Edibon Energy Losses in Bends Module FME05 was performed to measure the major and minor losses of water flow in pipes. The Technovate fluid circuit system, along with the formulas $Q = A_o C_d \sqrt{\frac{2\Delta P_{orifice}}{\rho(1-\beta^4)}}$ and $h_L = f \frac{L}{D} \frac{V^2}{2g}$ were used to calculate the flow rate (Q) and the major head loss ($h_L$). To calculate the Darcy friction factor (*f*), the Colebrook equation was used. The data collected from the two pipes of diameter 1.025 in ID and 0.43 in ID yielded $h_L$ values as low as 0.0127m to as high as 0.0324m. The experimental friction factor (*f*) ranged from 0.0245 to 0.0324. Minor losses were calculated in several fittings; three elbows, a mitre, and sudden contraction and sudden expansion fittings. Pressure drops were recorded across the inlet and outlet of each fitting and used to calculate $h_L$ minor from the equation $h_L = \frac{\Delta P}{\rho g}$. Losses were minimal as expected and varied only slightly ranging from 0.002m up to 0.038m. Experimental K values were also calculated from the equation $h_L = K \frac{V^2}{2g}$ and were estimated and found to be 0.398 to 1.12.

## Introduction:

Major and minor losses in the flow of any fluid are important factors to consider when designing a system for the purpose of moving a fluid from one point to another, and doing it efficiently. Applications such as pump sizing are factored heavily on these losses. Major losses are head losses due to friction factor and pipe diameter, and can vary depending on the type of pipe used. Minor losses are small losses due mainly to bends or valves that disrupt a smooth steady flow. Most minor losses are quantified as K values, loss coefficients, and for many types of fittings such as elbows, tee's, contraction/expansion fittings and valves such as globe, ball, and check valves, are readily produced.

In this experiment, major and minor losses were determined using the Technovate fluid circuit system (Appendix A) and the Edibon Energy Losses in Bends Module FME05 (Appendix B). Two pipes of diameter 1.025in ID and 0.43in ID, each 5ft long, were utilized from the Technovate system to determine how pipe diameter and volumetric flow rate effected the friction factor (*f*). The friction factor in fully developed turbulent flow also depends on the Reynolds number and the relative roughness $\varepsilon/D$ , which is the ratio of the mean height of roughness of the pipe to the pipe diameter. The functional form of the friction factor cannot be obtained from theoretical analysis, therefore the Colebrook equation is most often used as the best estimation of friction factor (Cengal and Cimbala, 2014).

The Edibon Energy Losses in Bends Module FME05 was used to calculate the minor losses. The module contained six different fittings for analysis of pressure drop. The pressure drops of each fitting were used to determine $h_{L\ minor}$ and K using the formula $h_L = K\frac{V^2}{2g}$.

## Objective:

The objective of this experiment was to approximate the effects of pipe diameter versus friction factor for major losses and to measure pressure losses due to pipe fittings for minor losses.

## Methods and Materials:

The Technovate fluid circuit system was used to determine major losses, friction factor and head losses. The flow rate of water through two pipes of inner diameter 1.025in and 0.43in was determined by measuring the pressure drops across an orifice flow meter. The dimensions of the orifice flow meter were d = .625in and $D_{inlet}$ = 1.25in. A minimum of six different flow rates were acquired for each pipe while never allowing the orifice pressure difference to be less than 5in and no greater than 25in. The pressure drops and flow rates of the pipes were used to determine the friction factor. The equation $h_L = f \frac{L}{D}\frac{V^2}{2g}$ was used to calculate $h_L$ using the friction factor (*f*), length (*L*), diameter (*D*) and velocity (*V*). The velocity was determine from the equation $V = \frac{Q}{A}$, where $Q$ is the volumetric flow rate.

The values for minor losses were quantified using the Edibon Energy Losses in Bends Module to aid in measuring the change in pressure across an assortment of pipe fittings. The fittings that minor losses were determined for were a long elbow, medium elbow, short elbow, right angle fitting (mitre), sudden expansion, and sudden contraction. Hoses were connecter to the inlets and outlets of each fitting and run to a series of manometric tubes. The change in pressure of each fitting was was reflected within its' respective manometric tube. These changes in pressure were used, along with measured flow rates, to determine the minor head loss for each fitting. The formula $h_L = \frac{\Delta P}{\rho g}$ was also used. Head loss ($h_L$) was then plotted against $V^2$ . The slope of the trendlines were used to estimate K, the losses coefficient, by manipulating the equation $h_L = K\frac{V^2}{2g}$ to solve for an experimental value for K. These values came out to range from 0.398 to 1.12. These experimental K values were also compare to theoretical values attained from section 8.6 of Fluid Mechanics: Fundamentals and Applications, Cengal and Cimbala.

## Results and Discussion:

Figure one shows how the friction factor (*f*) of a large diameter pipe is effected by velocity squared ($V^2$). The experimental and theoretical values were both plotted for comparison to each other as well as compared to $V^2$. The theoretical values in the figure slightly decrease and the experimental values slightly increase as $V^2$ increases. The difference between experimental and theoretical values is due to the difference in precision. Where as the theoretical values, in theory, would remain relatively constant because the theoretical equations do not take into account every factor that could effect the friction factor. The only way to obtain an exact experimental results that accurately reflect all of the influencing factors is to actually do an experiment. The graph actually reflects the different in theoretical and experimental data. The major loss is due to the diameter of the pipe.

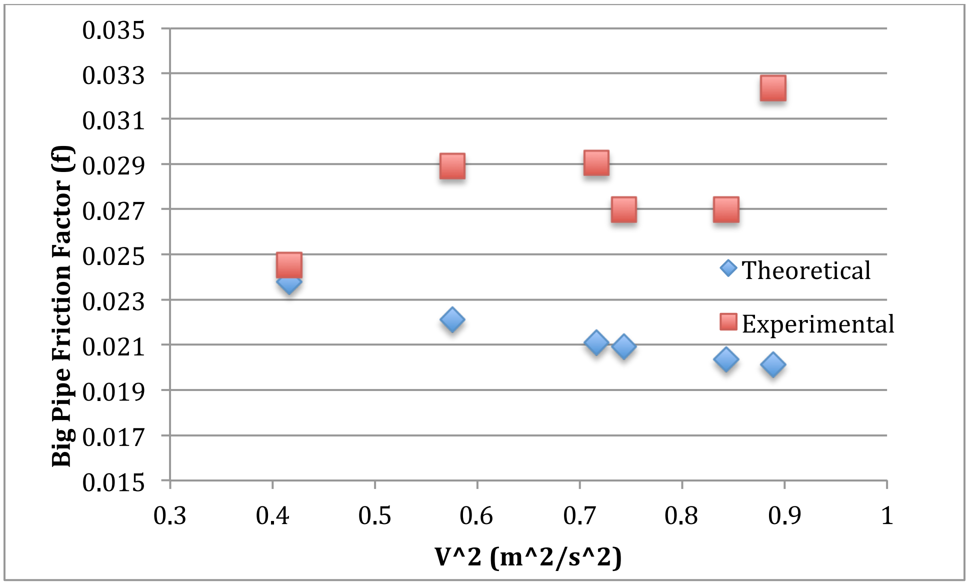


Figure 1 –Theoretical and experimental friction factor vs velocity squared for 1.025in ID pipe.

Figure 2 in a graph of data attained form the smaller pipe diameter friction factor compared to $V^2$. Again, the data shown is an analysis of how (*f*) related to $V^2$, and a difference in the precision of actual experimental data versus theoretical data. Both theoretical and experimental remain constant, give of take a few thousandths, as they decrease. For small pipe the friction loss due to diameter is significantly less than the loss for a larger pipe. This is to be expected since for a smaller pipe there is less diameter, therefore less opportunity to develop a large velocity profile resulting in a smaller friction loss. The theoretical friction factor is an underestimation of what the experimental data actually yields. Again, because the experimental data is from an actual experiment, it is more accurate than the theoretical data.

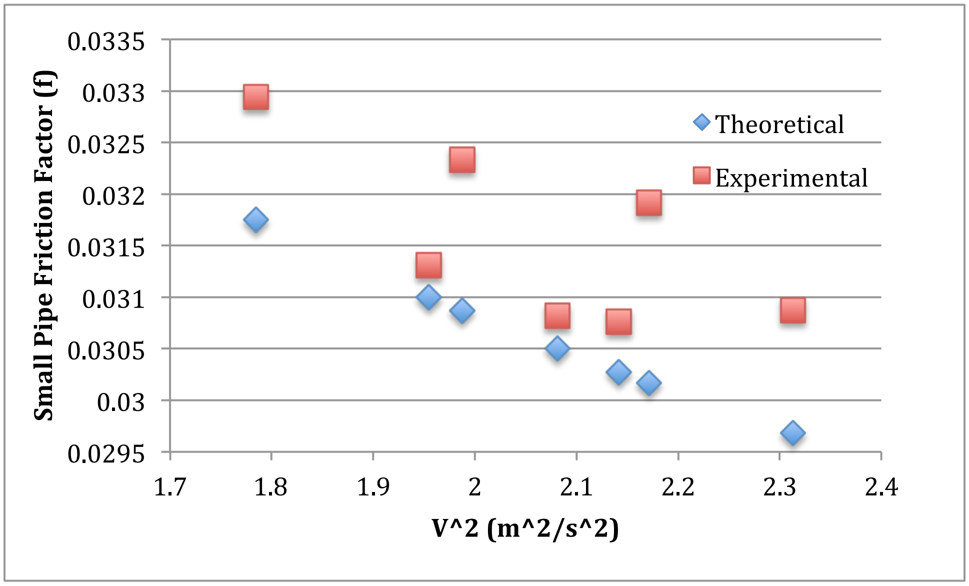


Figure 2 - Theoretical and experimental friction factor vs velocity squared for 0.43in ID pipe

Figure 3 below shows how minor head loss reacts as the square velocity increases. For all of the fittings except sudden expansion (widening), the head loss increases with $V^2$ . In general, the head loss coefficient, K, depends on the geometry of the fitting and the Reynolds number (Cengal and Cimbala, 2014). In most cases for internal fluid flow thought fitting the Reynolds number can be ignored. The mitre bend has the highest head loss because it is a rigid turn fitting. This will produce a high K value compare to a smooth long bend that will not disturb the flow as much. From the graph, the slopes of the lines gave approximate K values based on the fitting. The bigger slopes, higher $h_L$, will yield  higher value. As projected from the data in the graph, it was projected that the mitre and narrowing fittings yield the largest losses.

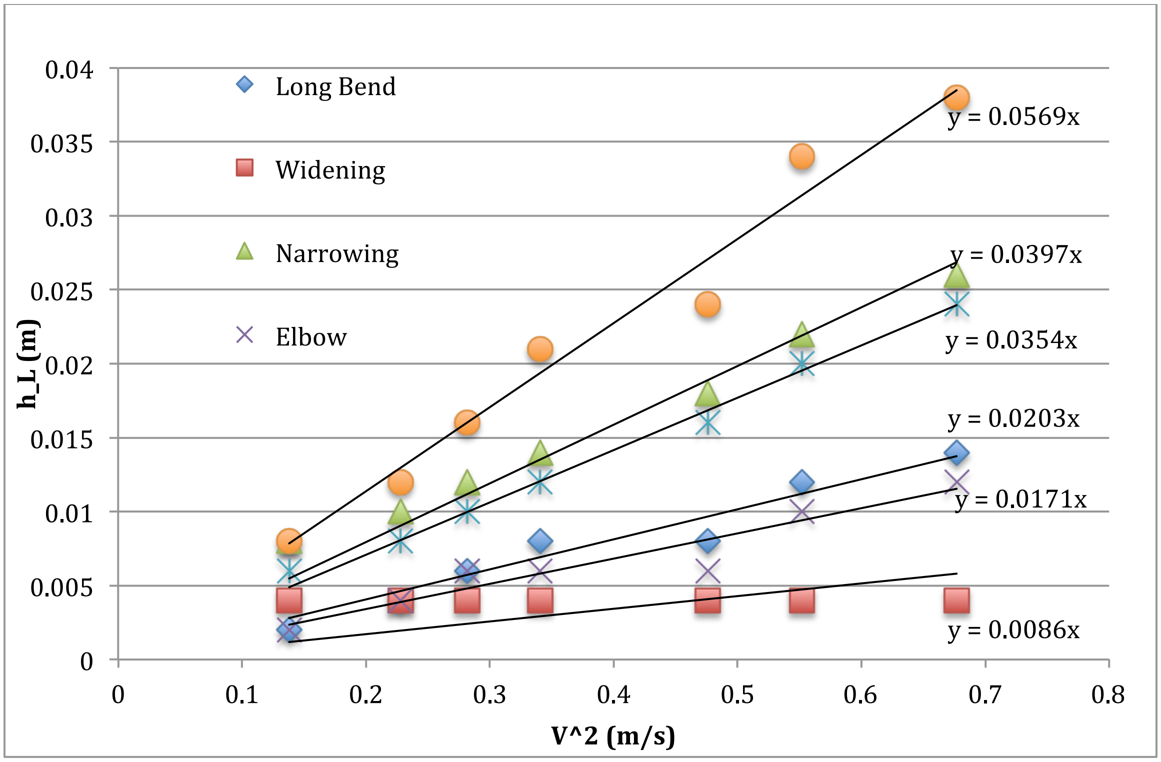


Figure 3 – Minor head loss due to velocity squared for six different fittings

Table 1. - Experimental and theoretical K values and percent error

| K Values | Experimental | Theoretical | % Error |
|---|---|---|---|
| Long Bend | 0.398286 | 0.6 | 33.62 |
| Widening | 0.168732 | 0.5906 | 71.43 |
| Narrowing | 0.778914 | 0.4 | 94.73 |
| Elbow | 0.335502 | 0.3 | 11.83 |
| Short Bend | 0.694548 | 0.9 | 22.83 |
| Mitre | 1.116378 | 1.1 | 1.49 |

Table 1 above provides experimental and theoretical K values for each type of fitting uses in the experiment. The mitre fitting had the smallest percent error between theoretical and experimental it was the simplest to approximate. A sharp turn of a fluid is going to result in height losses, therefore high loss coefficient. Due to its high losses, it is not a preferred fitting for most, if not all, fluid applications (Salyani, Serdynski, 1992). More practical and widely used fittings are elbows. As shown in table 1, they have a much lower K value due to how the flow of the fluid is turned.

With smooth turns, elbows, there is much less disruption and separation of the fluid, which yields less losses.

## Conclusion:

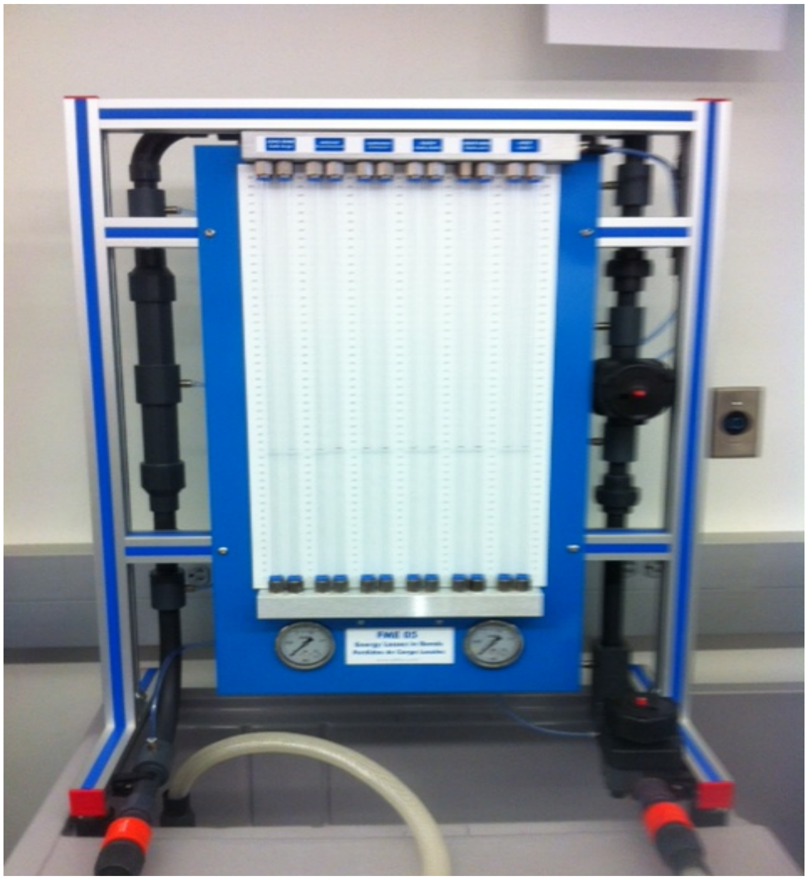
After all of the data was analyzed, the major and minor head losses were tallied up and compared to the theoretical values. For major losses the theoretical friction factor in both big and small pipes remained lower than the experimental value with an average percent error of 32.3% for the big pipe and 3.13% for the small pipe. For the minor losses there was an average percent error of 39.3% between the experimental ad theoretical K values, with the mitre fitting being the most similar between experimental and theoretical values at 1.5% error. However, if ample space is available, the mitre fitting would not be preferred compared to an elbow because it had the highest K value of 1.1 where as an elbow in among the lowest at 0.33.

## References:

Cengel, Y., & Cimbala, J. (2014). *Fluid mechanics: Fundamentals and applications* (Third ed., pp. 370-393). New York: McGraw-Hill.

Salyani, M., & Serdynski, J. (1992). A Device and Method for Sprayer Calibration. *Applied Engineering in Agriculture,* 29-32.

Appendix A



# Appendix B