MET 335

Module 9 – Friction Losses in Pipes and Fittings

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Purpose, Theory, and Procedure

1. **Experiment Title**
    a. Friction Losses in Pipes and Fittings
2. **Purpose**
    a. To determine the loss coefficient and equivalent length ratios of partially opened gate valves, and use found information to estimate how open the value itself is. We will calculate the resistance coefficient, Reynolds number, and valve equivalent length ratio for varying flow rates through the gate valve. We will determine the average equivalent length for the test runs and estimate the amount that the valve is open from supplied manufacturer specs for the given valves. To wrap the lab report up, we will discuss the results found as well as discuss the sources of error.
3. **Theoretical Considerations**
    a. Pipe diameter: 13.6mm
    b. Mass of water collected: 6kg
    c. Energy lost due to friction generated by the valve, recall Darcy's equation:
        i. $h_L = f\dfrac{LV_P{}^2}{D2g}$
    d. Define resistance coefficient:
        i. $K = f\dfrac{L}{D}$
    e. Resistance coefficient for valve:
        i. $K = f_\tau \dfrac{L_e}{D}$
        ii. Where L_e is the equivalent length
        iii. Where f_τ is the friction factor
    f. Combining equation c and e:
        i. $h_L = K(\dfrac{V_P{}^2}{2g})$
    g. Then, resistance coefficient can be calculated for the tested valve for each flow rate setting:
        i. $K = \dfrac{h_L}{\left(\dfrac{V_P{}^2}{2g}\right)}$
        ii. Where $h_L = (h_2 - h_1)$
    h. From the above, we can calculate the valve's equivalent length ratio for each flow rate setting:

i. $\left(\frac{L_e}{D}\right) = \frac{K}{f_T}$

i. Reynolds number:

i. $N_R = \frac{pVD}{\mu}$

ii. Assume $\in = 3x10^{-7}\,m$

j. Velocity flowing through the pipe containing the test valve:

i. $V_P = \frac{Q}{A_P}$

ii. $A_P = \frac{\pi D_P{}^2}{4}$

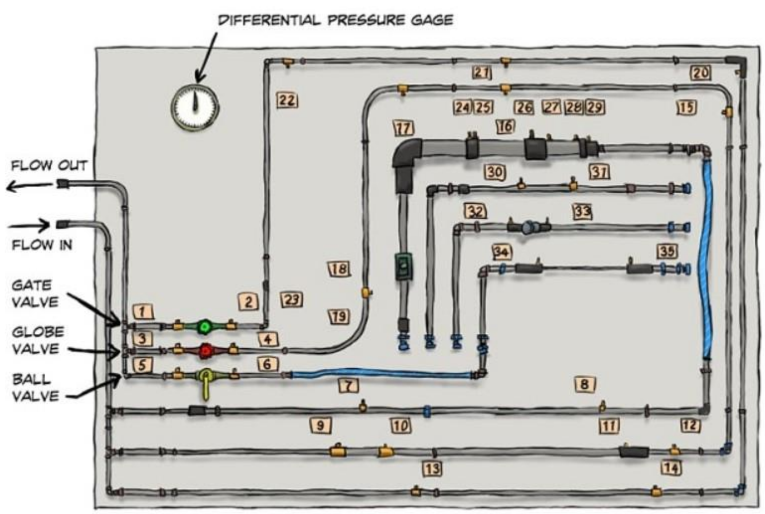
iii. $Q = \frac{\dot{m}}{p}$

iv. $p = 997\frac{kg}{m^3}$

k. Mass flow rate:

i. $\frac{Mass\,of\;water\,collected}{time\,to\;fill\,TANK}$

4. Drawing or Sketch



a. *Figure 1 - Fluid Friction Apparatus*

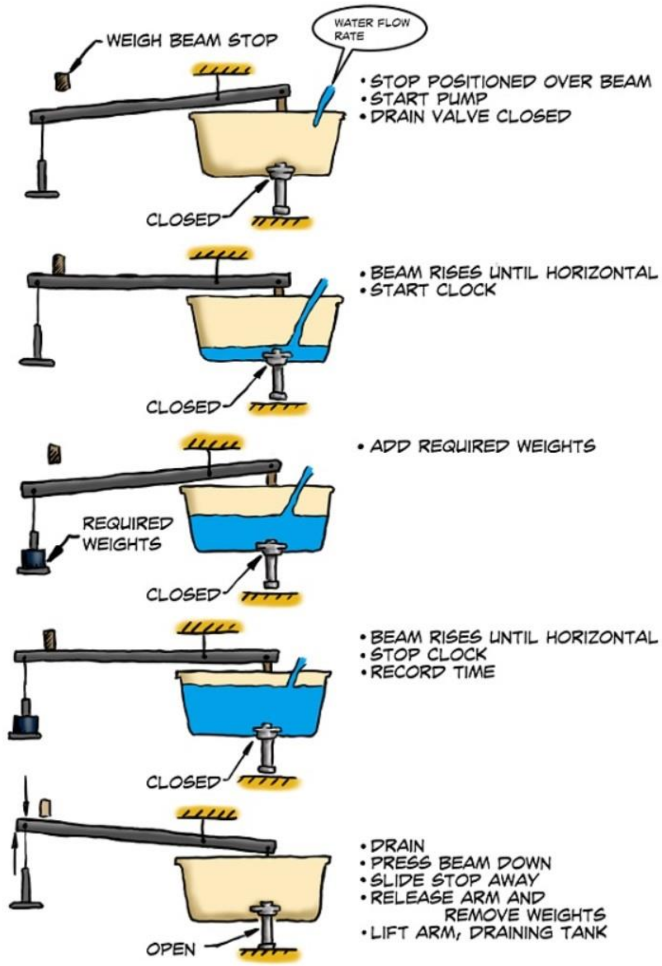
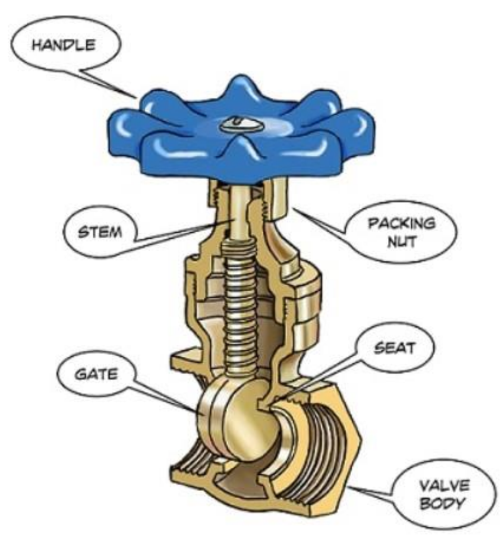
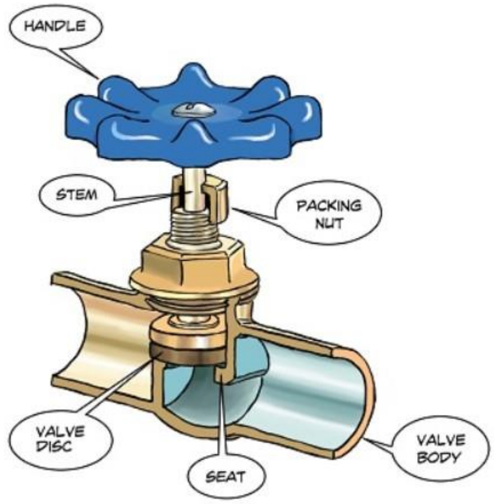


Figure 2 - Gravimetric Bench Operation

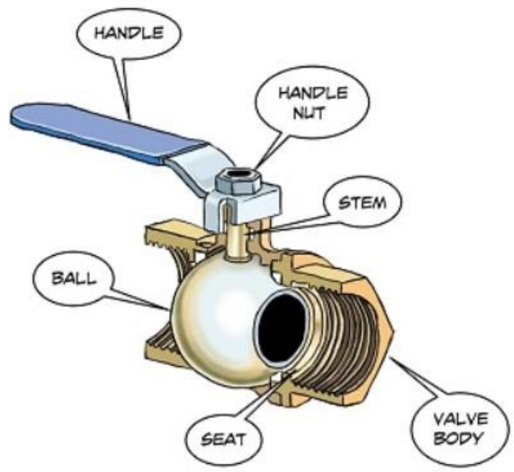
b.



c. *Figure 3 - Gate Valve*



d. *Figure 4 - Globe Valve*



e. *Figure 5 - Ball Valve*

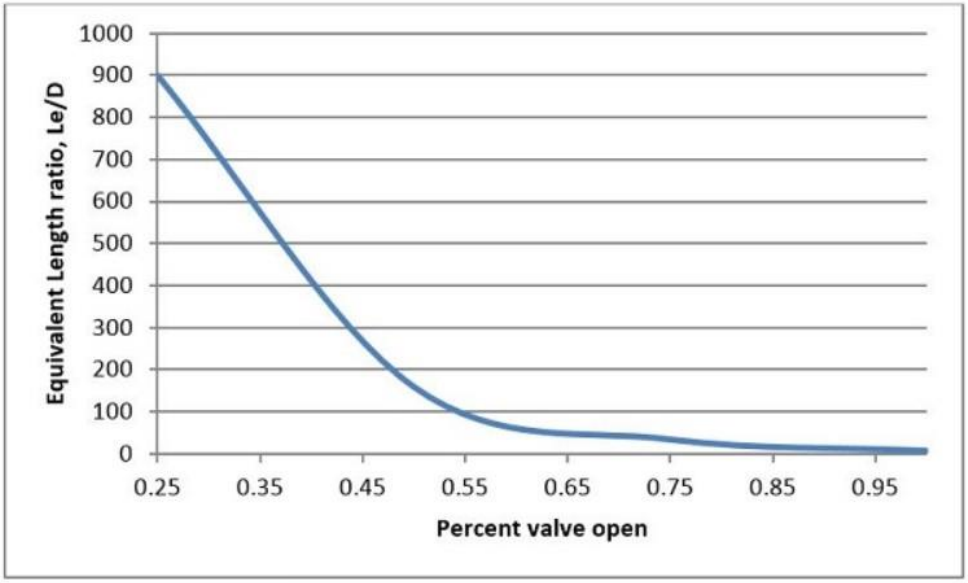


Figure 6 - A graph to plot the data

f.

Gate Valve Position	Equivalent Length Ratio
Wide open	8
¾ open	35
½ open	160
¼ open	900

g.

5. **Verbal Description**
   a. The above figures show a H408 Fluid Friction Apparatus and different valves and fittings that can be used in said apparatus. The apparatus consists of several different lengths and diameters of pipe with three different valves (gate, globe, ball). The apparatus itself contains 35 tapping points that transfer water to either the H408 Piezometer, a device that measures pressure in mm of H_2O, or a digital manometer. We will be using the digital manometer due to its ease of reading in this lab report. By isolating flow across the certain sections of pipe, we can determine the resistance coefficient, Reynolds number, and equivalent lengths using the equations in section 3. We will be using a pump and gravimetric bench to supply the apparatus with flow and measure mass flow rate (using the 6kg of water). The gravimetric bench is simply a device that is used to measure the mass flow rate of a fluid, water in our case. Using the three-to-one balance ratio, the mass of water collected in the bucket is three times that of the mass

supplied on the weight hanger. We will be adding a 2kg mass on the hanger, making it 6kg overall of water collected.

6. **Step-by-Step Procedure**
    a. Walked into lab room.
    b. Identified two main components used for the lab:
        i. Fluid Friction Apparatus
        ii. Water Collection Tank
    c. Identified the six components of the Fluid Friction Apparatus
        i. Digital Readout Box
        ii. Upstream Pressure Head Port
        iii. Gate Valve
        iv. Globe Valve
        v. Downstream Pressure Head Port
        vi. Ball Valve
    d. Identified the six components of the Water Collection Tank
        i. Flow Rate Valve
        ii. Weight Beam Stop
        iii. Gravimetric Bench
        iv. Pump Power Button
        v. Weight Platform
        vi. 2kg Weight
    e. Prepared equipment for use.
    f. Turned pump power on using black button.
    g. Rotated Red Flow Valve until maximum flow rate was achieved.
    h. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
        i. Waited a few seconds for the Gravimetric Bench to drop.
    i. Moved Weight Beam Stop to the left.
    j. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
    k. Placed 2kg Weight onto Weight Platform.
    l. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
        i. 31 secs.
    m. Selected the Downstream Pressure Head port to get the inches of water going downstream.
    n. Recorded inches of water going downstream from the Digital Manometer.
        i. 12.5 in
    o. Selected the Upstream Pressure Head port to get the inches of water going downstream.
    p. Recorded inches of water going upstream from the Digital Manometer.
        i. 34.8 in
    q. Selected Water Collection Tank to reduce the flow of water one rotation.

r. Selected Flow Rate Valve.
s. Rotated Flow Rate Valve one turn to the right.
t. Removed 2kg Weight from the Weight Platform to prepare to drain the Water Collection Tank.
u. Moved Weight Beam Stop to the right.
v. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
    i. Waited a few seconds for the Gravimetric Bench to drop.
w. Moved Weight Beam Stop to the left.
x. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
y. Placed 2kg Weight onto Weight Platform.
z. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
    i. 33 secs.
aa. Selected the Downstream Pressure Head port to get the inches of water going downstream.
bb. Recorded inches of water going downstream from the Digital Manometer.
    i. 12.6 in
cc. Selected the Upstream Pressure Head port to get the inches of water going downstream.
dd. Recorded inches of water going upstream from the Digital Manometer.
    i. 34.6 in
ee. Selected Water Collection Tank to reduce the flow of water one rotation.
ff. Selected Flow Rate Valve.
gg. Rotated Flow Rate Valve one turn to the right.
hh. Removed 2kg Weight from the Weight Platform to prepare to drain the Water Collection Tank.
ii. Moved Weight Beam Stop to the right.
jj. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
    i. Waited a few seconds for the Gravimetric Bench to drop.
kk. Moved Weight Beam Stop to the left.
ll. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
mm. Placed 2kg Weight onto Weight Platform.
nn. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
    i. 34 secs.
oo. Selected the Downstream Pressure Head port to get the inches of water going downstream.
pp. Recorded inches of water going downstream from the Digital Manometer.
    i. 12.7 in
qq. Selected the Upstream Pressure Head port to get the inches of water going downstream.

rr. Recorded inches of water going upstream from the Digital Manometer.
    i. 34.3 in
ss. Selected Water Collection Tank to reduce the flow of water one rotation.
tt. Selected Flow Rate Valve.
uu. Rotated Flow Rate Valve one turn to the right.
vv. Removed 2kg Weight from the Weight Platform to prepare to drain the Water Collection Tank.
ww. Moved Weight Beam Stop to the right.
xx. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
    i. Waited a few seconds for the Gravimetric Bench to drop.
yy. Moved Weight Beam Stop to the left.
zz. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
aaa. Placed 2kg Weight onto Weight Platform.
bbb. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
    i. 37 secs.
ccc. Selected the Downstream Pressure Head port to get the inches of water going downstream.
ddd. Recorded inches of water going downstream from the Digital Manometer.
    i. 14 in
eee. Selected the Upstream Pressure Head port to get the inches of water going downstream.
fff. Recorded inches of water going upstream from the Digital Manometer.
    i. 34.3 in
ggg. Selected Water Collection Tank to reduce the flow of water one rotation.
hhh. Selected Flow Rate Valve.
iii. Rotated Flow Rate Valve one turn to the right.
jjj. Removed 2kg Weight from the Weight Platform to prepare to drain the Water Collection Tank.
kkk. Moved Weight Beam Stop to the right.
lll. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
    i. Waited a few seconds for the Gravimetric Bench to drop.
mmm. Moved Weight Beam Stop to the left.
nnn. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
ooo. Placed 2kg Weight onto Weight Platform.
ppp. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
    i. 41 secs.
qqq. Selected the Downstream Pressure Head port to get the inches of water going downstream.

rrr. Recorded inches of water going downstream from the Digital Manometer.
    i. 14.2 in
sss. Selected the Upstream Pressure Head port to get the inches of water going downstream.
ttt. Recorded inches of water going upstream from the Digital Manometer.
    i. 31.3 in
uuu. Selected Water Collection Tank to reduce the flow of water one rotation.
vvv. Selected Flow Rate Valve.
www. Rotated Flow Rate Valve one turn to the right.
xxx. Removed 2kg Weight from the Weight Platform to prepare to drain the Water Collection Tank.
yyy. Moved Weight Beam Stop to the right.
zzz. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
    i. Waited a few seconds for the Gravimetric Bench to drop.
aaaa. Moved Weight Beam Stop to the left.
bbbb. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
cccc. Placed 2kg Weight onto Weight Platform.
dddd. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
    i. 43 secs.
eeee. Selected the Downstream Pressure Head port to get the inches of water going downstream.
ffff. Recorded inches of water going downstream from the Digital Manometer.
    i. 15.4 in
gggg. Selected the Upstream Pressure Head port to get the inches of water going downstream.
hhhh. Recorded inches of water going upstream from the Digital Manometer.
    i. 30.8 in
iiii. Selected Water Collection Tank to reduce the flow of water one rotation.
jjjj. Selected Flow Rate Valve.
kkkk. Rotated Flow Rate Valve one turn to the right.
llll. Removed 2kg Weight from the Weight Platform to prepare to drain the Water Collection Tank.
mmmm. Moved Weight Beam Stop to the right.
nnnn. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
    i. Waited a few seconds for the Gravimetric Bench to drop.
oooo. Moved Weight Beam Stop to the left.
pppp. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
qqqq. Placed 2kg Weight onto Weight Platform.

rrrr. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
    i. 48 secs.
ssss. Selected the Downstream Pressure Head port to get the inches of water going downstream.
tttt. Recorded inches of water going downstream from the Digital Manometer.
    i. 17.7 in
uuuu. Selected the Upstream Pressure Head port to get the inches of water going downstream.
vvvv. Recorded inches of water going upstream from the Digital Manometer.
    i. 30.3 in
wwww. Selected Water Collection Tank to reduce the flow of water one rotation.
xxxx. Selected Flow Rate Valve.
yyyy. Rotated Flow Rate Valve one turn to the right.
zzzz. Removed 2kg Weight from the Weight Platform to prepare to drain the Water Collection Tank.
aaaaa. Moved Weight Beam Stop to the right.
bbbbb. Used Gravimetric Bench to ensure no water in the Water Collection Tank.
    i. Waited a few seconds for the Gravimetric Bench to drop.
ccccc. Moved Weight Beam Stop to the left.
ddddd. Waited a few seconds for the Gravimetric Bench to rise as water fills the tank.
eeeee. Placed 2kg Weight onto Weight Platform.
fffff. Recorded time it took for the Gravimetric Bench to rise as the water filled the tank.
    i. 57 secs.
ggggg. Selected the Downstream Pressure Head port to get the inches of water going downstream.
hhhhh. Recorded inches of water going downstream from the Digital Manometer.
    i. 19.3 in
iiiii. Selected the Upstream Pressure Head port to get the inches of water going downstream.
jjjjj. Recorded inches of water going upstream from the Digital Manometer.
    i. 29.5 in
kkkkk. Selected Water Collection Tank to close any remaining water flow and shut off the tank.
lllll. Selected the Red Flow Valve to stop all water flow.
mmmmm. Removed 2kg Weight from Weight Platform.
nnnnn. Selected Gravimetric Bench to drain the water out.
    i. Waited a few seconds for Gravimetric Bench to drop.

ooooo. Turned Pump Power off by selecting red button.
ppppp. Lab successfully completed.

Recorded Data Table(s)

Tank Valve Position (red knob)	Time to Fill Tank (seconds)	Upstream Head, h_2 (location 2) (inches $H_2 0$)	Upstream Head, h_1 (location 1) (inches $H_2 0$)
1	31	34.8	12.5
2	33	34.6	12.6
3	34	34.3	12.7
4	37	34.3	14
5	41	31.3	14.2
6	43	30.8	15.4
7	48	30.3	17.7
8	57	29.5	19.3

Sample Calculations

$$\dot{m} = \frac{6kg}{31s} = \boxed{0.1935\frac{kg}{s}}$$

$$Q = \frac{\dot{m}}{p} = \frac{0.1935\frac{kg}{s}}{997\frac{kg}{m^3}} = \boxed{0.000194\frac{m^3}{s}}$$

$$A_P = \frac{\pi(13.6/100)^2}{4} = \boxed{0.01453m^2}$$

$$V_P = \frac{Q}{A} = \frac{0.000194\frac{m^3}{s}}{0.01453m^2} = \boxed{0.0134\frac{m}{s}}$$

$$\frac{V_P{}^2}{2g} = \frac{0.0134}{2*9.81} = \boxed{9.1\times10^{-6}}$$

$$K = \frac{h_2 - h_1}{\left(\frac{V_P{}^2}{2g}\right)} = \frac{0.5664m}{9.1\times10^{-6}} = \boxed{6.22\times10^4}$$

$$N_R = \frac{pVD}{\mu} = \frac{(997)(0.0134)(\frac{13.6}{100})}{0.000891} = \boxed{2034}$$

$$\frac{L_e}{D} = \frac{K}{f_T} = \frac{6.22\times10^4}{0.009656} = \boxed{6444292}$$

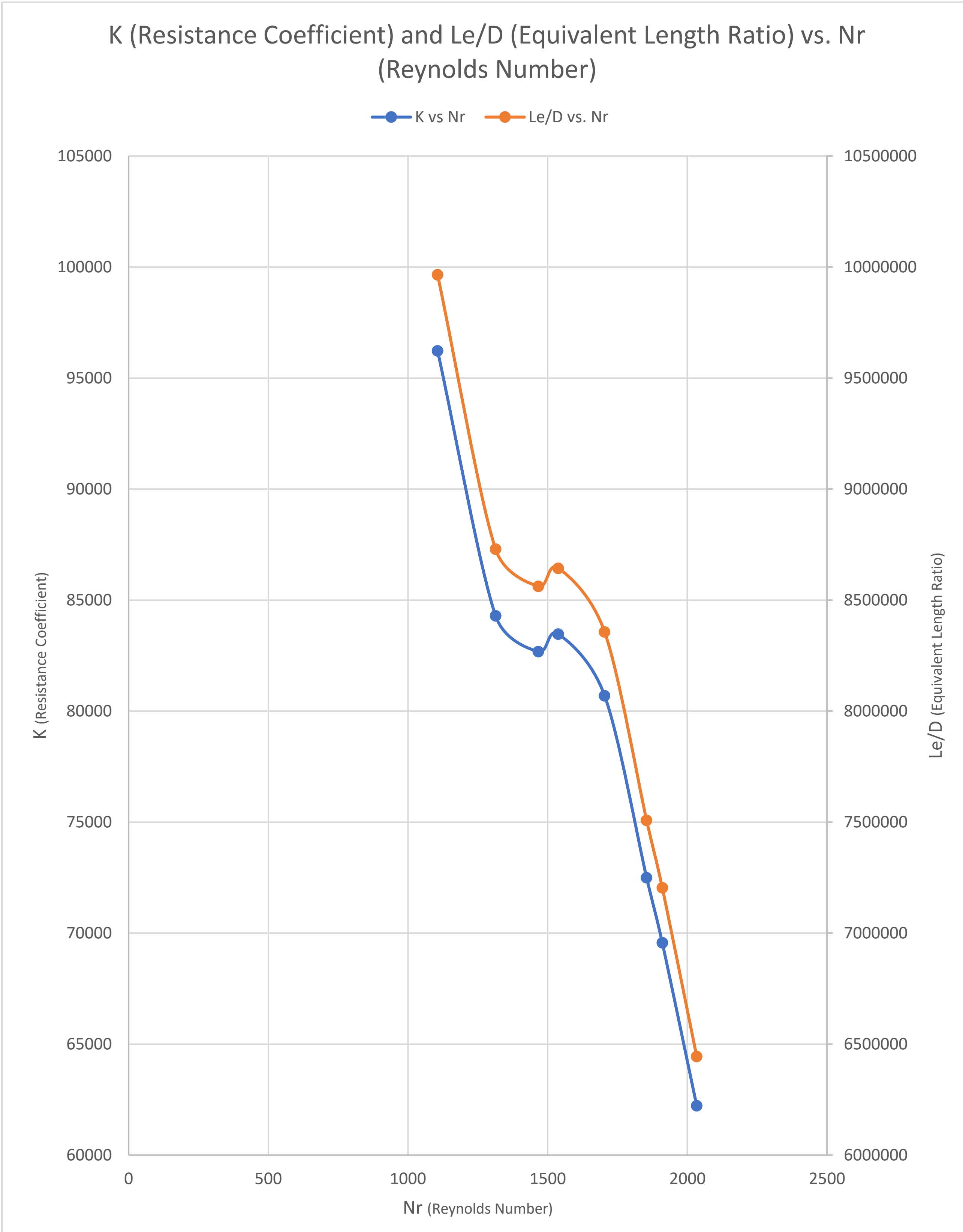
Calculated Data Table(s)

Tank Valve Position (red knob)	h_L (Energy loss) (m)	ṁ (mass flow rate) (kg/s)	Q (Volumetric flow rate) (m^3/s)	V_P (Velocity) (m/s)	$V_P^2/2g$
1	0.5664	0.1935	1.94E-04	0.0134	9.10E-06
2	0.5588	0.1818	1.82E-04	0.0126	8.03E-06
3	0.5486	0.1765	1.77E-04	0.0122	7.57E-06
4	0.5156	0.1622	1.63E-04	0.0112	6.39E-06
5	0.4343	0.1463	1.47E-04	0.0101	5.20E-06
6	0.3912	0.1395	1.40E-04	0.0096	4.73E-06
7	0.3200	0.1250	1.25E-04	0.0086	3.80E-06
8	0.2591	0.1053	1.06E-04	0.0073	2.69E-06

Tank Valve Position (red knob)	K (Resistance coefficient)	N_R (Reynolds Number)	f_T (Friction Factor)	L_e/D (Equivalent Length Ratio)
1	6.22E+04	2034	0.009656	6444292
2	6.96E+04	1910	0.009656	7204396
3	7.25E+04	1854	0.009656	7508593
4	8.07E+04	1704	0.009656	8356925
5	8.35E+04	1538	0.009656	8643922
6	8.27E+04	1466	0.009656	8562580
7	8.43E+04	1313	0.009656	8729714
8	9.62E+04	1106	0.009656	9965449

Tank Valve Position (red knob)	Estimated Valve Opening
1 (wide open)	0.85
2	0.8
3 (3/4 open)	0.75
4	0.55
5 (1/2 open)	0.5
6	0.35
7 (1/4 open)	0.25
8	0.15

Graph(s)



K (Resistance Coefficient) and Le/D (Equivalent Length Ratio) vs. Nr (Reynolds Number)
K vs Nr
Le/D vs. Nr
K (Resistance Coefficient)
Le/D (Equivalent Length Ratio)
Nr (Reynolds Number)
105000
100000
95000
90000
85000
80000
75000
70000
65000
60000
10500000
10000000
9500000
9000000
8500000
8000000
7500000
7000000
6500000
6000000
0
500
1000
1500
2000
2500

Discussion of Results and Conclusions

From the graphs above, we see that the calculations throughout the lab report give us a similar curve for each of the findings (K vs Nr) and (Le/D vs Nr). This gives me a little bit of confidence that we did the calculations right, however… we did have some rather large Le/D ratios and a substantial D/e calculation that wasn't even on the moody diagram. So, at the end of the day… we could be off on our calculations.

From the graphical curves above, it seems that the higher the Reynolds Number, the lower the K value or the Le/D value. So, this means that there is a direct correlation between these values and that the Reynolds Number is very critical to these calculations.

It also seems that the Le/D value is 100 times greater than the K value. This would be the variation difference between K and Le/D. To say which one seems more constant over the range of Nr values is tough to say because they follow a similar path, but for lab purposes I will say that the K value is more constant.

Some sources of error in this lab report are students not translating their units correctly. It's possible they kept the head loss findings in inches instead of converting from inches to meters. Another source of error could be not converting mm to m in the pipe area calculation. Another source of error potentially would be that the density value or the dynamic viscosity value was different from the standard 25°C findings in the back of the book (Applied Fluid Mechanics). All these sources of error pretty much domino effect into the final findings for this lab. So, it's very important to understand the units you are working with and the units you want to get to at the end of your calculations.