Orifice Flow Meter System

There are many different types of flow meters to measure internal flow: orifice plate, venture tube, flow nozzle, pitot tube, etc. These devices cause a change in velocity of the flow due to an area reduction. This change in velocity precedes a change in pressure which can be measured using a pressure gage or manometer.

The designed orifice flow-meter system is able to measure flow rates up to 6 GPM. The system consists of a plate with three different diameter orifices, each one for a different flow range.

Orifice #	Flow Range (GPM)	Orifice Diameter (in)
1	0-1	0.125
2	1-3	0.202
3	3-6	0.278

When using any particular flow range, the user must make sure to open the ball valves before and after that orifice and close all the other valves.

<u>Procedure:</u>

1. Make sure there is enough water in the water circuit tank.
2. Remove air bubbles from the whole system.
3. Open the appropriate ball valves to allow flow through the desired orifice.
4. Make sure all meters are on and control valve is closed.
5. Attach hoses to the pressure transducers and across desired orifice.
6. Turn on the pump.
7. Using the control valve, get the flow to the desired rate for the individual orifices.
    a. Ex. 0.7 GPM for orifice #1 (0-1 GPM) or 2.2 GPM for orifice #2 (1-3 GPM)
8. Record the controlled volume flow rate, change in pressure across the orifice, and the actual mass flow rate through the ABB K-flow meter in the chart below.
9. Repeat Steps 3-6 for a volume flow rate of 1 GPM for orifices #1 and #2 and 3 GPM for orifices #2 and #3.
10. Determine the volume flow rates using the two different meters. Calculate a percent error for the two flow meters. Also, calculate a percent error of the actual volume flow rates and the controlled.
11. Determine the actual K-value of the flow for each orifice and compare to the given set of K-values.

	Controlled Volume Flow Rate (GPM)	ΔP (inH2O)	Actual Mass Flow Rate (kg/min)
Orifice #1			
Orifice #2			
Orifice #3			

		Controlled Volume Flow Rate (GPM)	ΔP (inH2O)	Actual Mass Flow Rate (kg/min)
1 GPM	Orifice #1			
	Orifice #2			
3 GPM	Orifice #2			
	Orifice #3			

Special Notes:

The PVC pipe used is a 3/4" pipe, but when the inner diameter was measured, it was found to be 0.798". Maximum pressure for each orifice will be 20 psi (555 in_{H2O}). Once the pressure reading on display exceeds 555 in_{H2O}, it is best to switch to the next larger size orifice. When using orifice #3, the control valve can be opened all the way without exceeding the pressure reading.

Simplified Equations:

The following equation is used to determine the actual volume flow rate across an orifice.

$$Q_{actual} \equiv KA_2 \left(\sqrt[2]{\frac{2g_c}{\rho}} \right) (\Delta P)$$

This equation can be simplified for each orifice:

Flow Range (GPM)	Simplified Equations
0-1	$Q_{actual} \equiv 0.05587 \cdot \sqrt[2]{\Delta P}$
1-3	$Q_{actual} \equiv 0.15862 \cdot \sqrt[2]{\Delta P}$
3-6	$Q_{actual} \equiv 0.29454 \cdot \sqrt[2]{\Delta P}$

In these equations, Q_{actual} is in GPM (orifice flow meter volumetric flow rate). All the user has to do is take the reading (in inches of water) from the digital display and plug it into the above equations. The ABB K-flow flow meter gives readings in kg/min. In order to convert that to GPM, the user must divide the reading by 3.785. Readings from the two flow meters can now be compared.

K-Values:

Orifice #	Corresponding K-Value
1	0.757
2	0.8229
3	0.8068

The flow coefficient is found using the following equations:

$$Q_{Ideal} = \left[\frac{A_2}{\sqrt[2]{1-\left(\frac{A_2}{A_1}\right)^2}}\right] \cdot \sqrt[2]{\frac{2g_c\Delta P}{\rho}}$$

where Q_{Ideal} is the volumetric flow rate without losses.

$$E \equiv \frac{1}{\sqrt[2]{1-\left(\frac{A_2}{A_1}\right)^2}}$$

where E is the velocity of approach factor.

$$C \equiv \frac{Q_{k\ flow}}{Q_{Ideal}}$$

where C is the discharge coefficient.

$$K \equiv C \cdot E$$