

## Fluid Flow Design of Experiments Worksheet

Engineers are often asked to optimize a solution when exact formulas are not known. In the water distribution system you will build in the next activity, you will need to be able to predict the flow based on the capabilities of the pipe and pressure available to you.

When water flows through a pipe, the flow rate is a complex function of pressure, the inside diameter of the pipe, and the friction as a result of the fluid flow. Corners and restrictions, such as valves and other fittings, further affect the flow. This flow calculation is beyond the scope of this class so you will determine the flow characteristics through the various lengths of pipe, diameters of pipe, and fittings empirically – by measuring it. You will set up a design of experiments and then plot the results.

To do a design of experiments you must first determine the independent variables. In this case the variables are:

1. Water tower height
2. Tubing diameter ( $\frac{1}{2}$ " and  $\frac{1}{4}$ " )
3. Tubing length
4. The effect of fittings

You will make measurements at several water tower heights that cover the range that you might want to use in your simulated city. You will use 12", 24" and 36".

You will make measurements at various lengths of each of the two tubing sizes, again covering the range you will be using.

Finally you will measure the effect of adding an extra fitting to a length of tubing. The graphs should help you design your water distribution system even though you don't have accurate calculations from which to make predictions.

## Initial Set-up

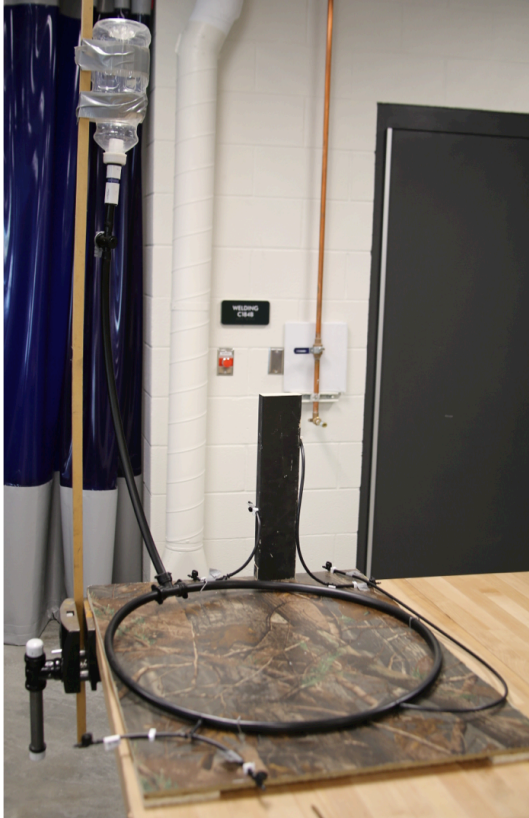
1. Drill several small holes or one large hole in the bottom of the bottle for refilling and venting.
2. Use duct tape to secure the bottle to a 1"x2" board that will be clamped in a bench vise. Place the bottle so that the water level in the bottle can be set to 12", 24" and 36" above the bench while the board is clamped into the vise. This will serve as the water tower for your activities.
3. Drill a hole in the juice bottle lid using a  $\frac{3}{4}$  in. spade bit. Apply very light pressure during drilling for a more uniform hole. Hold the lid in a clamp while drilling. Place a hose washer on the male connector and thread it through the inside of the lid. Place a second hose washer on male connector sandwiching the lid. Connect this assembly to the  $\frac{1}{2}$ " valve. Apply Teflon tape to threaded side of the flex pipe adapter. Thread it into the other side of  $\frac{1}{2}$ " valve and screw this assembly onto the bottle.



## Experiment

4. Fill the bottle and tubing with water until it is about 2" from the top of the bottle. Make sure all the air is out of the line, and that the valve is closed.
5. You will measure the flow rate (cc/sec) at each of the water tower heights. Best measurements will be obtained by plugging the end of the tubing with a finger, opening the valve and then releasing the water while someone else times you, then replacing your finger to stop the flow at the end of the time period. 5 seconds is recommended for this part of the lab. Record the flow rate (volume of water divided by time).
6. Add 10' of  $\frac{1}{2}$ " tubing to the bottle assembly to create a 10' water line. Perform the flow measurements at each of the three heights.
7. Kink the end of the long tubing to seal it. Attach a  $\frac{1}{4}$ " coupler to one end of a 36" section of  $\frac{1}{4}$ " tubing. Cut a hole somewhere along the length of the long  $\frac{1}{2}$ " tube and insert the coupler and 36" section of  $\frac{1}{4}$ " tubing into it. Measure the flow rate at each of the three heights. For the small tubing measurement of 10 to 20 seconds may be appropriate.
8. Cut off 12" of  $\frac{1}{4}$ " tubing and repeat the measurements for 24" of  $\frac{1}{4}$ " tubing. (Keep all sections of tubing you cut.)
9. Cut an additional 12" of tubing and repeat the measurement for 12" of  $\frac{1}{4}$ " tubing.

10. Add a 90° elbow and repeat the measurements.
11. Finally, cut the ½" tubing at 4' from the bottle outlet and repeat the measurements one final time. (Keep the section of tubing you cut off for the next day's lab.)



### Analysis

12. Graph each data point using the x-axis for water tower height. Draw a line through each group of three measurements from the same row in the table and the line. Consider how will plot the wide range of data on the y-axis.
13. What flow rate would you predict for an 18" line of 1/4" tubing at 24" water tower height? Why?
14. What flow rate would you predict if two 90° elbows were placed in a 24" line with a 24" pressure head? Why?

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