

Lab 7: The Influence of Reynolds Number in Pipe Flows

Purpose

The purpose of this experiment is to illustrate the influence of Reynolds number on pipe flows. Reynolds number is a very useful dimensionless quantity (the ratio of dynamic forces to viscous forces) that aids in classifying certain flows. For incompressible flow in a pipe, Reynolds number based on the pipe diameter, $Re_D = V_{ave}D\rho/\mu$, serves well. Generally, laminar flows correspond to $Re_D \leq 2100$, transitional flows occur in the range $2100 < Re_D < 4000$, and turbulent flows exist for $Re_D > 4000$. However, disturbances in the flow from various sources may cause the flow to deviate from this pattern. This experiment will illustrate laminar, transitional, and turbulent flows in a pipe.

Apparatus

The apparatus used in this experiment provides a means of visually observing the different pipe-flow regimes of an incompressible fluid, water in this case. A diagram of the apparatus is shown in Fig. 1. Water is supplied to the tank on the left through the water supply line and valve. A constant water level is maintained in the tank by overflow into the standpipe. The water in the tank flows through a section of "fill", a collection of small spheres held in place by screens. The purpose of this arrangement is to produce a low turbulence flow downstream of the fill. The water enters the transparent observation tube through a rounded entrance. Blue dye is injected into the stream to provide the visual effect. A pump is used to force the dye into the injection tube and to control the rate at which it is injected. The pump has controls with a digital dial that can be set (on an arbitrary scale) to deliver dye from a very slow to a relatively fast rate. It also has a button (MAX) that when pressed delivers the maximum dye injection rate the pump is capable of delivering. It is useful for some flows to press and quickly release the MAX button to inject a spurt of dye and then observe the motion of the dye in the flow.

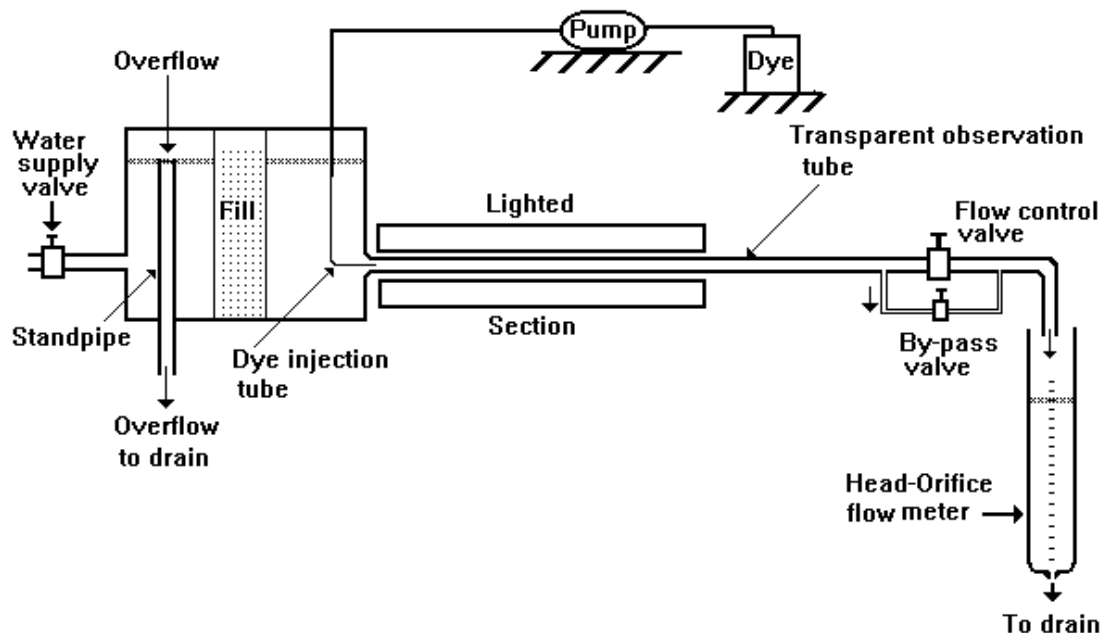


Fig. 1 Apparatus for studying laminar, transitional, and turbulent pipe flow

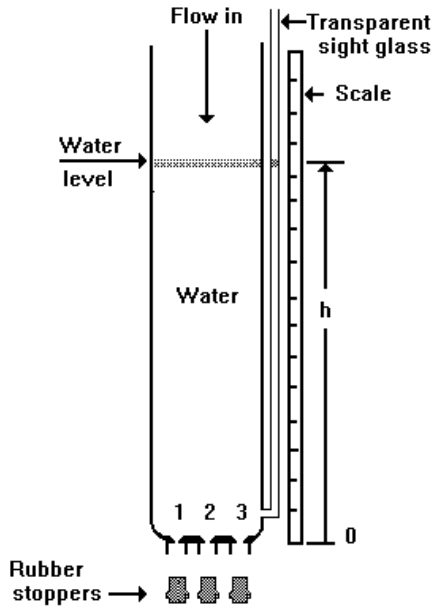


Table 1. Orifice information

Orifice #	Dia., inches	Velocity coef.* = $V_{\text{actual}}/V_{\text{ideal}}$
1	0.100	0.926
2	0.160	0.933
3	0.250	0.898

* Determined by meter calibration.

Fig. 3 Schematic diagram of the head-orifice water flow meter.

The apparatus includes the head-orifice flow meter shown in Fig. 1 and in more detail in Fig. 2. This allows rapid determination of the Reynolds number for the flow in the observation tube. The meter consists of a closed-end tube in which flow from the observation tube is collected. Three orifices that meter the flow are located in the bottom of the closed end. These can be used selectively by inserting rubber stoppers in orifices not used. As the head h increases, the flow rate through an orifice (or a combination of orifices) increases. When the flow rate out of an orifice (or a combination of orifices) equals the flow rate into the meter from the observation tube, the head h will be established at a fixed value. The flow rate is related to the h and the size of the orifice (or orifices) selected. This flow rate can then in turn be used to determine the Reynolds number in the observation section of the apparatus. Thus, for a given orifice or (a selection of orifices), the observation tube Reynolds number based on inside diameter D ($= 0.750$ inches) is directly related to the head h . Table 1 gives information on the orifices of the head-orifice flow meter. The velocity coefficient defined in the table, accounts for non-ideal flow through an orifice. $V_{\text{ideal}} = (2gh)^{1/2}$.

Figure 4 is a graph of Re_D vs. head for the head-orifice meter for each orifice and certain combinations of orifices. The curves incorporate the velocity coefficients.

Figure 8.3 in your text describes what you can expect to see in the transparent observation tube for the three flow regimes. The flow through the pipe is controlled by the upstream water supply valve, and the down steam flow-control and bypass valves. For very low flow rates (and low Reynolds number), the flow control valve should be closed and the flow should be regulated by the bypass valve. For high flow rates (higher Reynolds number) the bypass valve should be closed and the flow should be regulated by the flow control valve. For all flows, the water supply valve should be adjusted to maintain a small overflow into the standpipe shown in Fig. 1.

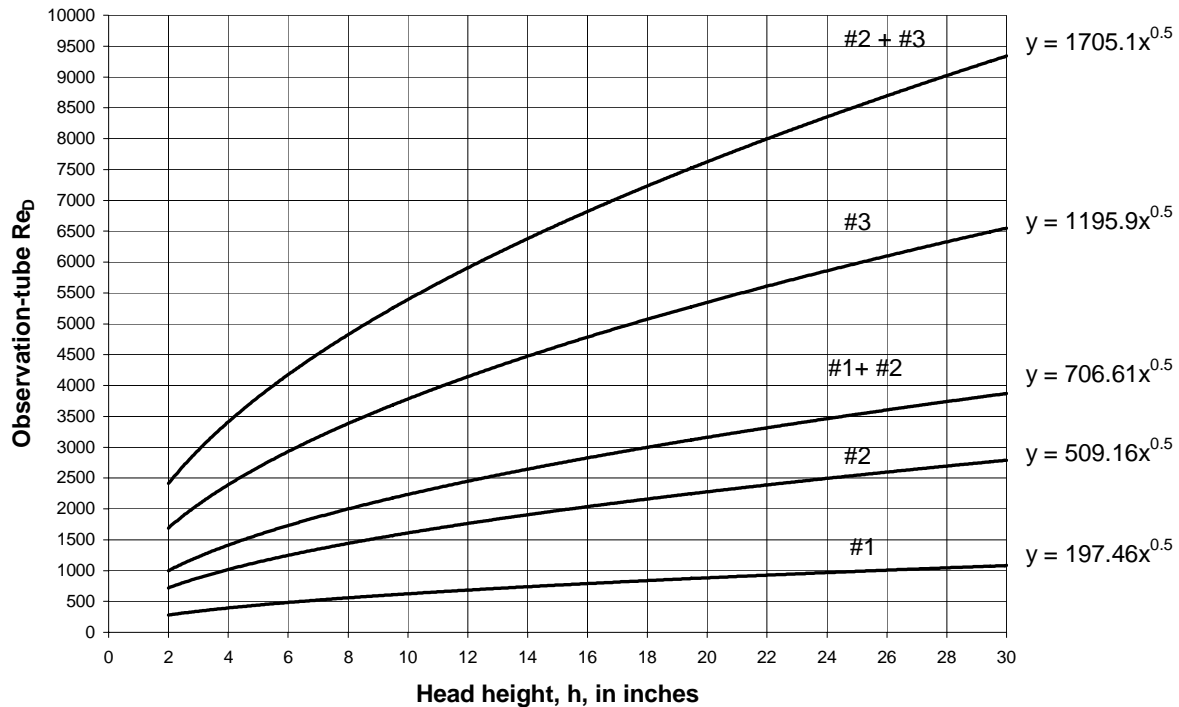


Fig.4 Observation tube Reynolds number versus head. $T_{H_2O} = 60^\circ F$.

Procedure

1. Prepare a data spreadsheet to record all of the pertinent information.
2. Conduct a series of runs. Use a digital camera (if available) to record the patterns made by the dye in the observation tube or sketch the pattern if the camera is not available. Start with a very low flow rate (and Reynolds No.) by closing the flow control valve and using the small bypass control valve to regulate the flow. Increase the flow rate gradually and eventually reach the fully turbulent regime. Select orifices as necessary to cover the three flow regimes. Make sure the equilibrium value of h is established before using Fig. 4 to obtain Reynolds number. Be sure to identify as closely as possible the Reynolds number for transition from laminar to turbulent flow.

Keep in mind the following while conducting this experiment.

- Disturbances in the flow from several sources may alter the Reynolds number at which transition from laminar to turbulent flow takes place.
- To minimize flow disturbances, a smooth properly-contoured entrance section to the observation tube is required. This may not be the case in the apparatus used in this experiment.
- The presence of the dye injection tube may cause flow disturbances that may affect transition.
- Injection of the dye at a velocity different from the water velocity may unduly disturb the flow.
- In some cases, disturbances related to dye injection will die out with distance along the observation tube and laminar flow will clearly exist.

- You may not be able to clearly define the Reynolds number at the limit of laminar flow or the range over which transitional flows occur, but you should clearly observe laminar in low Reynolds number flows and turbulent flows in high Reynolds number flows.
- For at least at the higher values of Reynolds number in the laminar flow regime, the flows you are observing are not fully developed in the lighted section of the observation tube. An indication of this can be obtained from the calculation of L_e/D from equation Eq. (8.1) in your text. Eq. (8.2) gives L_e/D for turbulent flows. Flow development length for turbulent flows tend to be shorter than are those in the laminar flow regime.
- The dye is not neutrally buoyant and tends to sink in the flow.

Report

Submit a short form report on the results, observations, and conclusions of this study. Discuss the nature of the flow in the laminar, transition, and turbulent regimes. Include photographs or sketches of typical dye patterns of each type.

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ReNoRigN.bmp
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