

**MEMORANDUM**

**DATE: August 26, 2009**

**TO: Laboratory Group C**

**FROM: Tony Butterfield**

**Engineering Training Supervisor**

**SUBJECT: Liquid Flow Bench**

Our client is interested in mixing two solutions within standard piping, rather than in a commercial mixer. One liquid, Liquid A, is a dilute aqueous base. Before they are able to dispose of Liquid A as waste, they must bring it to a neutral pH. They hope to do this using a concentrated acid solution, Liquid B, from another process. Fortunately, you will be working with neither base nor concentrated acid. Suffice it to say, they are interested in mixing two such streams.

As luck would have it, the sight tube section of pipe and the die injection tube on our liquid flow bench are near the required dimensions for the piping for Liquid A and B respectively. You are to use this sight tube and die injection system to study the mixing of these two solutions at various flow rates.

The client wishes to understand the degree of mixing as a function of the time and distance from the point the two liquids come into contact. They are unsure at what flow rate they will pump the solutions or what length of pipe they will use. They are also unsure how quickly they dare mix their acid and base solutions. Therefore, please collect data at a variety of Reynolds numbers.

Note that I ran this piece of equipment yesterday and found that turbulent flow was difficult to achieve. We hope to remedy this issue before you begin, but, if we cannot, simply collect data at the highest flow rate you can achieve and several lower flow rates.

Your report should include data that is more quantitative than your subjective opinion of where along the tube adequate mixing occurs. I have written for you a simple matlab program that will extract and analyze the distribution of blue from jpg images. I suggest you use digital photographs of the die flowing in the tube and fix a tape measure to the top for distance measurements. For the program to give you the best results, the tube should fill as much of the image to be processed as possible, with the tape measure at the top. You may crop images taken from a distance in order to cut down on the number of images needed for each flow condition; just keep in mind that you will want to be able to read the tape measure. It is not expected that you will show images or plot the resulting data for every flow rate you study, but we would like to see, at least, a characteristic example from laminar, turbulent and transition flow (or, if turbulent flow cannot be achieved, three different non-turbulent flows). Please, see me for examples of how to use this program to quickly get useful data from images, even if you feel it is self explanatory.

Keep in mind that shadow, glare, and imperfections in the tube may cause problems (remember to take images with the same exposure, throughout your project). The cylindrical geometry, projected onto a 2D image will lead to an artifact as well.

For the laminar case, the flow profile should be parabolic. Is the flow rate at the center of the tube what one would expect from theory? Is the flow apparently laminar at the Reynolds numbers one would expect? Please understand that, while dispersion will occur with laminar flow, you are not required to find and use the model for that process.

For turbulent flow, as a general rule of thumb it is assumed about 10 times the diameter in pipe length is needed to have adequate mixing. If you can reach turbulent flow, does that rule of thumb seem reasonable in the light of your data?

Because we are concerned about the rate of mixing, due to the exothermic reaction, be sure to somehow measure and report on this rate, as a function of flow rate. Finally, in your report, please comment on any difficulties you suspect our client might find in translating your findings to their application.

Before you begin I recommend you read the manual kept at the liquid flow bench; it has detailed operating instructions for the sight tube, and describes some possible problems you may face. If you have any questions regarding this project or what is expected of you, please feel free to contact me at any time. I look forward to our meeting on or before Wednesday, September 9th, 2009.