Linear Chemical Dose Controller

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Abstract

The linear chemical dose controller, LCDC, is a key technology for AguaClara. The LCDC makes it possible for the plant operator to directly set the chemical dose for the coagulant. The LCDC is a combination of several technologies and although the AguaClara team has been developing these technologies since 2004, there is still a critical need to improve the performance and accuracy of the LCDC. The immediate priority is to be able to understand, quantify, and minimize the minor losses for a given CDC setup so that we can make system adjustments and improvements to decrease the minor losses. The next step is to build dose controllers for different design flow rates and test them. An alternative is modify our design protocol and set the maximum coagulant flow rate for all plant sizes smaller than 20 $\frac{L}{s}$ to be 2 $\frac{mL}{s}$.

students	3 FT
skills	fluid mechanics, fabrication, experimental methods, data analysis

1 Minimize and Characterize Minor Losses

The minor losses scale with $\frac{V^2}{2g}$ and thus don't have the linear relationship between head loss and flow rate that we need for the linear chemical dose controller. These minor losses cause a departure from linearity and thus an error in the chemical dosing. Our goal is to minimize the minor loss coefficient and to increase the major losses sufficiently so that the error caused by the minor losses is acceptable small. The minor losses are caused by contraction and then flow expansion at the entrance, additional shear due to the initial high velocity gradients at the wall of the tube, expansions at fittings, expansion or jet discharge.

Modify the LCDC test apparatus to use barbed fittings that have inner diameters that are at least as large as the inner diameter of the tube. This will reduce the minor loss coefficient by eliminating expansions and contractions at the entrance and exit of the barbed fittings.

Quantify the head loss through the entrance region (the region where the parabolic velocity distribution has yet to develop) of the small diameter tube in terms of a minor loss coefficient (k-value). The entrance region of the tube has

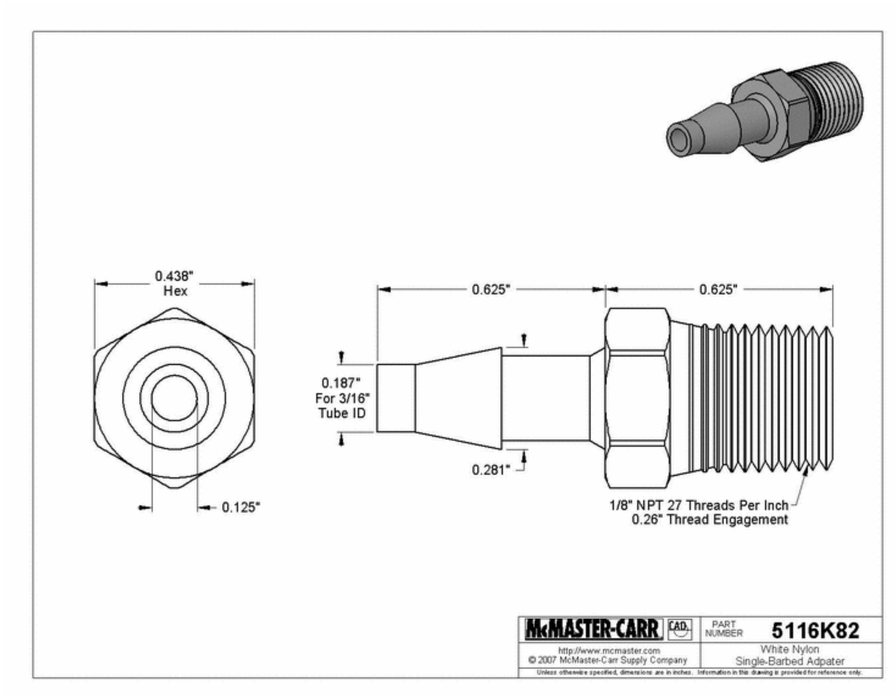

Figure 1: Barbed fitting with inner diameter equal to the tubing inner diameter.

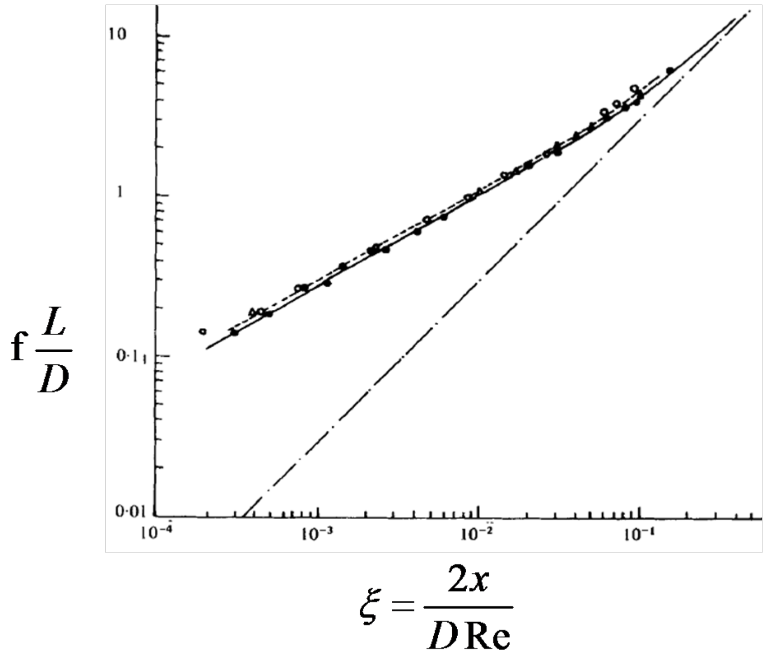

Figure 2: Entrance losses characterized experimentally[1].

higher shear due to the higher velocity gradient at the wall of the tube. This increased energy loss is characterized by Mohanty and Asthana[1].

Mohanty and Asthana (1978) characterize the total head loss in the entrance region. The total loss is the sum of the major loss $\left(f\frac{L}{D}\right)$ and the minor loss (K) due to the additional wall shear.

$$\frac{P_0 - P}{\frac{1}{2}\rho V^2} = f\frac{L}{D} + K \tag{1}$$

The minor loss coefficient approaches a value of 1.15 for values of $\xi = \frac{2L}{DRe}$ exceeding 0.12 (see Figure 3) (Mohanty and Asthana, 1978). The value of ξcorresponding to 0.12 represents the transition to fully developed flow with a parabolic velocity distribution.

The exit losses for laminar flow are expected to have a loss coefficient value of 2 because of the parabolic velocity distribution. The kinetic energy content of the fluid in laminar flow is twice that of the same flow with a uniform velocity rather than the parabolic velocity profile. Although the entrance loss is measured to be 1.15, only 0.15 of that represents the loss of mechanical energy to thermal energy. A value of 1 represents the conversion of potential energy to kinetic energy with the parabolic velocity profile. The parabolic velocity profile in a tube has twice the kinetic energy that the same flow would have with uniform velocity

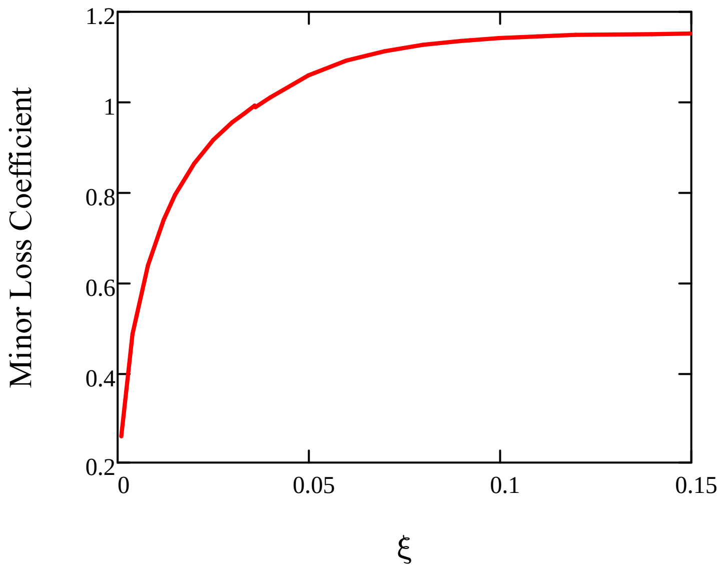

Figure 3: The minor loss coefficient corresponding to the losses in excess of major losses in the entrance region for laminar flow.

The sum of the minor loss coefficients is:

- Entrance: 0.5 (rough estimate for the sharp edged entrance)
- Entrance region: 0.15
- Exit: 2.0 (all of the kinetic energy is lost when the jet exits the tube)
- Total: 2.65

The minor loss coefficient total is must less than what is observed in practice with the LCDC. It is possible that curvature of the tube is a significant additional loss. The effect of tube curvature on losses is presented in [2].

1. Investigate the effect on minor head loss of the radius of curvature of the small diameter tube. Are these head losses significant?

2. Determine the trade-off AguaClara wants to make regarding small diameter tube length and CDC system maximum percent error. From our results, we see that a longer tube reduces maximum percent error. How long is too long for a small diameter tube? What is the tradeoff here?

3. Design an easy way for the plant operator to measure the plant's current flow rate and decide where, in the entrance tank, to place the label to measure it. Currently the operator's label the LFOM. Is that the best

approach? Could the lever system include a read out for the plant flow rate?

4. Test the screw that fastens the slider to the lever. Will this screw wear out over time? Will it be damaged if alum or PACl is spilled on it? This will be important not only for the CDC but also to choose which of the new flow controller designs to implement. Test the reducer to see what its maximum chemical flow rate is for various tube lengths.

5. Devise a method to generate labels using AutoCAD or some other method that can be automated and included with the design files.

6. Evaluate the possibility of producing LCDCs with set maximum flow rates. Instead of calibrating the LCDC, the fill volume for the stock tank would be set so that when a bag of coagulant is added it produces a concentration that delivers the correct dose given the max flow of the LCDC. All the LCDCs would be the same over a wide range of plant flow rates and the stock tank concentration would be varied.

7. Develop a method to calibrate a new LCDC so that it produces the design flow rate.

8. Evaluate the possibility of placing a plant flow rate scale on the LCDC. Compare with the option of placing a scale on the LFOM. Choose the best option and implement the solution.

References

[1] A. K. Mohanty and S. B. L. Asthana, Journal of Fluid Mechanics / Volume 90 / Issue 03, pp 433 - 447, 1978. Published online: 19 April 2006 `DOI:10.1017/S0022112079002330`

[2] Zhou, Y., & Shah, S. (2006). New Friction-Factor Corrections for Non-Newtonian Fluid Flow in Coiled Tubing. SPE Drilling and Completion , 68-76 (`DOI:10.1017/S0022112079002330`).