Spiral Tubing Design

Spiral Tubing Design

Summary

One of the proposed designs for incorporating the alum doser was to use long, spiraled tubing that connects the alum stock to the influent water entering the filter. Calculations were done in order to determine the parameters associated with the spiral tubing. Unfortunately, it was discovered that in order for this design to work, the exit tubing would need to be approximately 3.5 meters in length. This is too large for the desired size of our unit.

Calculations

Download the Spiral Tubing Design MathCAD File here.

The user inputs the maximum turbidity (used to determine the alum dose concentration), the desired flow rate of alum (converted to liters/day), and the diameter of tubing, which is used to determine the area of tubing. The inner diameters of available tubing can be found on McMaster-Carr: http://www.mcmaster.com/#tubing/=bdk5q3.

$$MaxTubidity := 10$$ **user input**

$$C_{AlumDose} := \left(\frac{MaxTubidity}{5}\right)\cdot 1.5\frac{mg}{L} = 3\cdot\frac{mg}{L}$$

$$Q_{AlumDose} := 1\frac{mL}{s} = 86.4\cdot\frac{L}{day}$$ **user input**

$$D_{Tube} := 3mm$$ **user input**

$$A_{Tube} := \pi\cdot\left(\frac{D_{Tube}}{2}\right)^2 = 0.011\cdot in^2$$

The head loss in the tube was determined using the equations for major and minor losses. The equations used in these calculations were found in online AguaClara notes and in Frank M. White's Fluid Mechanics (6th Edition).

$$Re(Q,D,\nu) := \frac{4\cdot Q}{\pi\cdot D\cdot \nu}$$ Equation for reynolds number

$$f(\varepsilon,D,Re) := \begin{cases} \dfrac{64}{Re} & \text{if } Re < 2100 \\ \dfrac{.25}{\left(\log\left(\dfrac{5.74}{Re^{0.9}} + \dfrac{\varepsilon}{3.7\cdot D}\right)\right)^2} & \text{otherwise} \end{cases}$$ Equation for friction factor

$$h_f(Q,D,f,L_{tube}) := f\cdot\frac{8}{g\cdot\pi^2}\cdot\frac{L_{tube}\cdot Q^2}{D^5}$$ Equation for Major Loss

$$h_e(K,Q,D) := K\cdot\frac{8\cdot Q^2}{g\cdot\pi^2\cdot D^4}$$ Equation for Minor Loss

$$h_t(h_f,h_e) := h_f + h_e$$ Total Head Loss = Major Head Loss + Minor Head Loss

Next, we work backwards to determine the necessary head loss through the alum doser to achieve the previously defined flow rate. The file uses the user defined dimensions for the alum doser and the head loss calculated from these dimensions to determine the head loss through the system. The equations utilized come from head loss calculations for a "hole in the bucket" situation.

$$VenaContracta := .62$$ set parameter: vena contracta

$$H_{StockLevel} := 5in$$ **user input**

$$H_{Tubing} := 2in$$ **user input**

$$Head_{Loss} := \left| \left(\frac{Q_{AlumDose}}{A_{Tube} \cdot VenaContracta} \right)^2 \cdot \left(\frac{1}{2 \cdot g} \right) - H_{StockLevel} - H_{Tubing} \right| = 0.175m$$

To determine the required length of tubing, it is assumed that minor losses are negligible and that only shear forces (or major losses) need to considered, given that the diameter of the spiral is wide enough such that we can neglect the loss coefficient. This implies that the curved portion of the spiral is very slight and is therefore negligible in calculations pertaining to head loss. The required tubing length is calculated from the head loss that was previously determined.

$$\nu := 1 \times 10^{-6} \frac{m^2}{s}$$ set parameter: kinematic viscosity

$$Re_{Tube} := Re\left(Q_{AlumDose}, D_{Tube}, \nu\right) = 424.413$$

Means laminar flow.

$$\varepsilon_{PVC} := .0015mm$$ set paremater: roughness of pvc material

$$f_{Tube} := f\left(\varepsilon_{PVC}, D_{Tube}, Re_{Tube}\right) = 0.151$$

$$L_{Tube} := \frac{Head_{Loss}}{f_{Tube}} \cdot \left(\frac{g \cdot \pi^2}{8} \right) \cdot D_{Tube}^{\ 5} \cdot \left(\frac{1}{Q_{AlumDose}^{\ 2}} \right) = 3.415m$$

Given the length of tubing, we determine the number of spirals needed and the circumference of the bucket in which the spirals will be wrapped around. Then, based on the thickness (or outer diameter) of the tubing, the total thickness or height when all the spirals are touching is calculated to ensure that the thickness is less than the user-thickness. If this is the case, the spacing between each spiral is calculated for extra constructability information.

$$D_{5GalBucket} := 12in$$

$$C_{5GalBucket} := 2 \cdot \pi \cdot \left(\frac{D_{5GalBucket}}{2} \right) = 0.958m$$

$$N_{Spirals} := \frac{L_{Tube}}{C_{5GalBucket}} = 3.566$$

$$Outer_{DTube} := 5mm$$

This is for the tube with a 3 mm inner diameter.

$$T_{Spirals} := N_{Spirals} \cdot Outer_{DTube} = 0.702 \cdot in$$

The thickness (or height) of all the spirals tubings stacked together with no spacing in between.

$$S_{BetweenSpirals} := \frac{H_{Tubing} - T_{Spirals}}{N_{Spirals}} = 9.246 \cdot mm$$

Again, it should be stated that this design would not work well with our point-of-use unit. The tubing length of 3.5 meters is too long and almost ridiculous to include in our filtration system. We can most definitely find a better way to design this component.