Problem of the Day

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A 14-inch diameter force main flows full. The lift station pump discharging to the force main pumps 650 gpm. It is 1.8 miles from the lift station to the discharge point. What is the detention time in the force main, in hours, when the pump is running?

Introduction

This is the fourth in a series of Problems of the Day looking at the operation of a lift station discharging to a force main. In yesterday's Problem of the day the volume of sewage in the force main was calculated to be 75,924 gallons. In water and wastewater treatment, operators are often tasked with calculating how long it takes to fill a tank or reservoir, how long it takes to empty a tank or reservoir, or what the detention time is in a tank or reservoir. Or a pipe, for that matter! The equation is the same for calculating all of these:

$$T = \frac{V}{Q}$$

where T is time, V is volume and Q is flow into or out of the tank or reservoir.

This seems like a pretty straightforward equation to me. What makes it difficult is that the units of T, V and Q may not be consistent. This is not a concern when using the solution bridge: V is entered into the numerator of the solution bridge in whatever units it is given in (or calculated), Q is entered into the denominator of the solution bridge in whatever units it is given in, and whatever conversion factors are necessary to get T in the units requested are used. Just remember the equation is the same for all problems with T, V and Q.

Solution

The problem statement gives the following information in units used by WWTT:

1. Pipe diameter, d = 14 in
2. Pipe flowing full (since force mains, by definition, flow under pressure, they will always be flowing full)
3. From a previous Problem of the Day, flow through (cross sectional) area, A = 1.068 ft^2
4. Pipe length = 1.8 mi
5. From the previous Problem of the Day, volume in the pipe, V = 75,924 gallons
6. Pumping rate, Q = 650 gal/min

The question specifically asks to find the detention time in hr so these units are put between heavy vertical lines, as always, followed by an equals sign and the blank solution bridge.

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$$|\ hr\ | = \frac{\quad}{\quad}$$

The equation given above is used to start the solution bridge. First, volume, V (No. 5), is entered,

$$|\ hr\ | = \frac{75{,}924\ gal}{\quad}$$

which is then divided by the flow, Q (No. 6), canceling gal,

$$|\ hr\ | = \frac{75{,}924\ \cancel{gal}}{650\ \cancel{gal}} \times \frac{min}{\quad}$$

The only thing left to do is to convert minutes to hours.

$$\text{hr} = \frac{75{,}924\ \cancel{\text{gal}}}{650\ \cancel{\text{gal}}} \times \frac{\cancel{\text{min}}}{60\ \cancel{\text{min}}} \times \frac{\text{hr}}{}$$

Since all the unwanted units have now canceled and only the units needed in the answer remain (**hr**), we know the solution bridge is complete. The arithmetic gives the answer.

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$$\text{hr} = \frac{75{,}924\ \cancel{\text{gal}}}{650\ \cancel{\text{gal}}} \times \frac{\cancel{\text{min}}}{60\ \cancel{\text{min}}} \times \frac{\text{hr}}{}$$

75,924 ÷ 650 ÷ 60 = **1.95 hr**.

Discussion

We have already said that the velocity in the force main is low, which is a red flag. The calculation of detention time in the force main, here, is another red flag. The 1.95 hr calculated is a detention time you'd expect in a primary clarifier. And what if the pump doesn't run for 1.95 hours each cycle? This has "septic" written all over it. More tomorrow.

Happy calculating! Let us know, by leaving a comment, if you want us to do a specific problem, if you see a mistake, or if you have a question on any of the Problems of the Day you are looking at.