Problem of the Day

2015.Aug.13

Problem of the Day

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. Flow into the lift station's wet well averages 612,000 gpd. The wet well is 10 feet long by 10 feet wide. When the water depth in the wet well reaches 14.5 feet, a float turns the pump on. A second float turns the pump off when the water depth is 1.0 ft. How long does it take (hours) to fill the wet well from the 1-ft elevation to 14.5 ft?

Introduction

This is the sixth 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 draw down time was calculated to be 0.748 hr, which is not enough time to completely flush the force main which has a detention time of 1.95 hours when the pump is running. Similar to but different from yesterday's Problem of the Day, today's problem asks to calculate how long it takes to fill the wet well, of known volume, with a constant flow of 612,000 gal/d into it. During this fill time, the pump taking sewage out of the wet will not be running. Again, the equation is the same for calculating all fill time, empty time and detention time problems:

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

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

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. Wet well operating dimensions = 10 ft by 10 ft by 13.5 ft (14.5 ft − 1.0 ft = 13.5 ft)
6. Pumping rate, Q_{out} = 650 gal/min
7. Influent flow rate, Q_{in} = 612,000 gal/d

Once the wet well level is brought down to the 1.0 ft level, the 650-gpm pump turns off. The wet well fills at the 612,000 gal/d rate until the float at 14.5 ft turns the pump back on. This is a simple "fill time" calculation.

The question asks to calculate the fill 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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$$|\ hr\ | = \text{\_\_\_\_\_}$$

The equation given above is used to start the solution bridge. First, volume, V of the wet well (No. 5), is entered l x w x d,

$$|\ hr\ | = \frac{10\ ft \quad 10\ ft \quad 13.5\ ft}{\text{\_\_\_\_\_}}$$

which is then divided by the flow into the wet well (No. 7),

$$\text{hr} = \frac{10\ \text{ft} \times 10\ \text{ft} \times 13.5\ \text{ft} \times \text{d}}{612{,}000\ \text{gal}}$$

Using the well known conversion factor, ft^3 (ft x ft x ft) and gal are canceled.

$$\text{hr} = \frac{10\ \text{ft} \times 10\ \text{ft} \times 13.5\ \text{ft} \times \text{d} \times 7.48\ \text{gal}}{612{,}000\ \text{gal} \times \text{ft}^3}$$

To get the units needed in the answer, d have to converted to hr.

$$\textbf{hr} = \frac{10\ \text{ft} \times 10\ \text{ft} \times 13.5\ \text{ft} \times \text{d} \times 7.48\ \text{gal} \times 24\ \textbf{hr}}{612{,}000\ \text{gal} \times \text{ft}^3 \times \text{d}}$$

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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10 x 10 x 13.5 x 7.48 x 24 ÷ 612,000 = **0.396 hr**.

Discussion

The time it takes to fill the wet well just calculated, 0.396 hr, plus the time it takes to empty the wet well calculated yesterday, 0.748 hr, is how long a complete cycle takes, 1.144 hr. That means the pump cycles about 21 times a day, which seems reasonable. The detention time in the force main, however, remains a concern. One more calculation 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.