Problem of the Day

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A secondary clarifier has a side water depth of 18 feet. It is 120 feet in diameter and the depth in the center is 23 feet. The tank is empty when the influent gate is opened. Flow into the tank averages 18.1 MGD while it is being filled. The RAS pump pumps 10,000 gpm but is not turned on until the tank is full. How many hours does it take to fill the tank?

Introduction

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. 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. Again, this equation is used to calculate 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.

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 as in today's problem), 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:

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

Solution

The list of "givens" expressed in the units used by WWTT:

1. Secondary clarifier diameter = 120 ft
2. Side water depth = 18 ft
3. Center depth = 23 ft
4. Influent flow = 18.1 Mgal/d
5. RAS flow = 10,000 gal/min (not relevant in this problem since no RAS pumping until tank is full)

The dimensions given for the secondary clarifier tell us it has a conical bottom and the depth of the cone is 5 ft (23 ft − 18 ft = 5 ft). The total secondary clarifier volume, then, is the sum of the volume of the cylindrical portion (V_{cyl}) plus the volume of the conical portion (V_{cone}). These are calculated here in Mgal. You should know how to calculate volume of cylindrical and conical tanks. Using units assures you are doing the calculations correctly.

V_{cyl} Mgal	=	0.785	120 ft	120 ft	18 ft	7.48 ~~gal~~	Mgal
						ft^3	10^6 ~~gal~~

V_{cyl} = 0.785 x 120 x 120 x 18 x 7.48 ÷ 1,000,000 = 1.522 Mgal.

V_{cone} Mgal	=		0.785	120 ft	120 ft	5 ft	7.48 ~~gal~~	Mgal
		3					ft^3	10^6 ~~gal~~

V_{cone} = 0.785 x 120 x 120 x 5 x 7.48 ÷ 3 ÷ 1,000,000 = 0.141 Mgal.

The total volume of the secondary clarifier is:

$V = V_{cyl} + V_{cone}$ = 1.522 Mgal + 0.141 Mgal = 1.663 Mgal.

The question specifically asks to find how many hours it takes to fill the tank so the units hr are put between heavy vertical lines, as always, followed by an equals sign and the blank solution bridge.

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

The equation above tells us how to start the solution bridge: V is entered in the numerator and Q is entered in the denominator.

$$|\ \text{hr}\ | = \frac{1.663\ \cancel{\text{Mgal}}}{\quad} \cdot \frac{\text{d}}{18.1\ \cancel{\text{Mgal}}} \cdot \frac{\quad}{\quad}$$

Even if you couldn't remember the equation, we know from the units that this is the only way V and Q can be used in the solution bridge to get volume (Mgal) to cancel **and** to get a unit of time (in this case d) in the numerator because a unit of time (in this case hr) is needed in the answer. All that remains is the conversion of days (d) to hours (hr). By using the solution bridge we don't have to think about whether we divide or multiply by 24, because the units tell us what to do. This is very important under the pressure of an exam, believe me.

$$|\ \textbf{hr}\ | = \frac{1.663\ \cancel{\text{Mgal}}}{\quad} \cdot \frac{\cancel{\text{d}}}{18.1\ \cancel{\text{Mgal}}} \cdot \frac{24\ \textbf{hr}}{\cancel{\text{d}}}$$

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

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$$|\ \textbf{hr}\ | = \frac{1.663\ \cancel{\text{Mgal}}}{\quad} \cdot \frac{\cancel{\text{d}}}{18.1\ \cancel{\text{Mgal}}} \cdot \frac{24\ \textbf{hr}}{\cancel{\text{d}}}$$

1.663 x 24 ÷ 18.1 = **2.2 hr**.

Discussion

This is a very typical problem. Remember, whether you are calculating how long it takes to fill a tank or reservoir or how long it takes to empty a tank or reservoir or what the detention time is in a tank or reservoir, the equation is the same, only the units differ.

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.