Media Filtration: Are Two Tanks Sufficient?

Even though sand media filters are one of the most popular types of filters used in irrigation and are able to perform well in a wide variety of conditions, they do have some design limitations. Unlike screen and disc filters, sand media filters have a minimum flow-rate limitation, as well as a maximum flow-rate limitation.

This is because fine silts and clays can penetrate deeply into the media bed under low velocity and low flow conditions and reach the underdrain before there is an appreciable pressure differential. If the filtration system has an automated time clock controller set to back-flush periodically (every six hours or so, depending on water quality), the minimum flow-rates can be designed as low as 10 to 15 gallons per minute per square foot (gpm/ft2) of media surface. In a non-automated system, the minimum flow recommendations are around 17 gpm/ft2 to prevent contaminates from reaching the underdrain prior to a back-flush sequence.

On the high flow-rate end, screens and disc filters are basically limited to the point of acceptable pressure loss. Media tanks, on the other hand, are limited to a certain high flow-rate because of disruption to the bed of sand. Under high flow-rate conditions, high velocity water enters the media tank, strikes the diffusion plate and is deflected towards the outside wall of the tank. If the velocity is high enough, the water scours the sand away from the wall, and deposits it underneath the deflection plate, forming a volcano shaped cone of sand. In many cases this "coning" process is severe enough to expose the gravel pack or underdrain system, and the filtration is compromised.

In response to this phenomenon, most media tank manufacturers have designed features into the diffusion plates to minimize the coning problems associated with high velocity water, and the maximum flow-rates can approach 25 to 30 gpm/ft2 before coning becomes a problem.

The challenge in media filtration selection therefore becomes an issue of maintaining a relatively narrow range of flow-rates through the filter. At first glance, this does not appear to be too much of a challenge: Determine the required flow rate, and select a tank combination from a manufacturer's catalog that falls within the window of operating flow-rates of 17 to 25 gpm/ft2. Where's the challenge?

The challenge is to maintain the flow-rate "window" not only during the filtration sequence, but during the back-flushing sequence as well. The flow characteristics of the filtration system during back-flush is markedly different than during the normal filtration process. Also, the number of media tanks in series in the filtration "battery" plays a significant role in the dynamics of the system.

To illustrate this point, let's look at two options for filtering a flow-rate of 500 gpm: A two-tank battery (two 48" diameter tanks) and a four-tank battery (four 36" diameter tanks). A 48" tank has 12.5 ft2 of surface area, so two tanks have 25 ft2 between them. A flow-rate of 500 gpm divided by 25 ft2 is 20 gpm/ft2, an excellent rate for good filtration.

A 36" tank has 7.1 ft2 of surface area, or 28.4 ft2 for four tanks. The flow of 500 gpm divided by 28.4 ft2 is 17.6 gpm/ft2, also within the range for good filtration. Both the batteries of four 36"-tanks and two 48"-tanks will filter the water adequately. What about the back-flush cycle?

During back-flush, one of the tanks in the battery is closed to the unfiltered water inlet, and opened up to the flush discharge manifold. Filtered water from the tank(s) that is not flushing flows backward into the flushing tank through the underdrain and lifts the sand media in a process called "fluidization". The fluidized sand bed floats up and the particles that were trapped in the bed are released. These particles are carried by the flush water through the flushing manifold and disposed of in the waste water system. The flow rate of the back-flush is critical to properly fluidize the sand bed without flushing all of the sand out through the flush manifold, and is determined by the tank diameter and manufacturer. The flow rate is generally adjusted with a gate valve on the back-flush manifold. A typical back-flush flow-rate for a 48" tank is 200 gpm, and a 36" tank is 110 gpm.

When we begin the back-flush sequence in the two 48"-tank battery, one of the tanks closes and begins flushing 200 gpm into the waste water system. The non-flushing tanks now carries the entire 500 gpm flow required by the irrigation system plus the 200 gpm flushing requirement of the other tank. If the water supply pump can deliver it, the non-flushing tank will have 700-gpm flowing through it. That calculates as 700 gpm divided by 12.5 ft2 of surface area, which equals 56 gpm/ft2. This is twice the maximum design flow rate, and a definite candidate for coning.

When the four 36"-tank system begins to back-flush, one of the tanks closes and begins to flush 110 gpm into the flush manifold. The remaining three tanks of the battery now share the 500 gpm required by the irrigation system and the additional 110 gpm flush-water flowing through the flushing tank. This calculates as a total of 610 gpm divided by three tanks, or 203 gpm per tank. 203 gpm divided by 7.1 ft2 per tank equals 28.6 gpm/ft2 of filtration surface area, which is still within the design parameters of the tank. The four-tank battery will not be as likely to cone as would the two-tank battery, which experiences high flow rates in the non-flushing tank during a back-flush sequence.

There is another option that may be considered when selecting media filtration batteries. By placing a pressure-sustaining valve downstream of the filter system, it may be possible to control the flow-rate of the irrigation system. A pressure-sustaining valve senses the water pressure upstream, and begins to close down if the water pressure drops below a pre-set level. If the system is being fed by a centrifugal or turbine pump, closing the valve will reduce the flow-rate and the pressure will increase to a corresponding point on the pump's performance curve.

Let's look at our hypothetical example of the two 48"-tanks with a 500-gpm operational flow rate. When a back-flush sequence is initiated, only one of the tanks will be filtering, and we can determine what we want the maximum flow rate to be through that tank. Let's say that we do not want any more than 30 gpm/ft2 flowing through the single tank. With a surface area of 12.5 ft2 multiplied by 30 gpm/ft2, we determine the maximum flow rate to be 375 gpm.

We now consult our pump performance curve, and determine that the pump will produce the normal operating flow of 500 gpm at 30 psi, as an example. It will also produce 375 gpm at 45 psi, let's say. So what we want the pressure-sustaining valve to do is shut down until 45 psi is sustained against the pump, but only during a back-flush sequence. (We still require the 500 gpm for normal operation). We can accomplish this by having the pressure-sustaining pilot actuated with an electric solenoid valve that is controlled by the automatic back-flush controller…Whenever the controller signals a back-flush sequence, it also signals the pressure-sustaining pilot to close down to 45 psi. The resulting flow through the non-flushing filter will be held to 375 gpm by the pump performance curve.

We must keep in mind that under this scenario, 200 gpm will be used to flush the other media tank and only 175 gpm will be sent out to the field as irrigation water. This will result in a severe drop in field pressure and an associated loss in irrigation uniformity. It will, however, prevent the media filters from coning, thereby jeopardizing the entire system by lack of proper filtration.

The reason why two-tank batteries are popular is simple: Price. The customer compares the cost of a two-tank system to cost the four-tank system without the understanding of the back-flushing dynamics, and chooses the less expensive option every time. If we figure the cost of a pressure-sustaining valve into the two-tank system, the price difference shrinks dramatically. Add into the equation the losses of irrigation uniformity and effective run-time while the two-tank system is back-flushing, and the four-tank system begins to make more economic sense.

Calculating the best combination of media tank diameter and number of tanks in the battery for any given flow rate can be done in the manner of the examples provided above, but the math has already been worked out for us. A table of flow rates and flushing rates is provided along with an excellent discussion of this topic in the book "DRIP and MICROIRRIGATION for Trees, Vines and Row Crops" by Charles Burt and Stuart Styles, which is available from The Irrigation Training & Research Center, California Polytechnic State University, San Luis Obispo, CA 93407, (805) 756-2434.

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