Loose Media Filtration (Tank-Type)

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The functioning of a good loose-media pressure filter system depends upon several critical factors. First and foremost is proper water analysis to determine the objectionable constituents that must be reduced or removed. Second, the hydraulic parameters of available water pressure and flow rate available in US gallons, or in liters per minute (L/min.), must be learned. On well pump systems, the sustained flow rate is very important as it will be a guide in the sizing selection relative to backwashing. On city water supplies, available flow rate is not usually a concern unless low pressure (under 25 psi) is apparent.

A quick way to verify the available flow rate on a pump system at a private well source is to open one (cold) faucet fully, wait until the pump kicks in, and then, with the pump still running, time the number of seconds it takes to fill a 5 US gallon pail or 19 liter container.

Table 1-1 provides some reference measurements for this important determination.

The basic question is, will the flow rate be high enough to properly backwash the size filter required for the home or business need? One of the most common reasons for filter failure is inadequate flow rate for backwashing, which results in the filter media becoming clogged and the occurrence of channeling. As a rule of thumb, filter backwash rates are always greater than the rated service (filtering) flow rate. In order to match the service flow rate with available flow rate from a pump, it may be necessary to install two or more smaller diameter filter units, operating parallel but backwashing sequentially.

Most domestic pumping systems on private wells are only capable of 5 to 7 US gpm flow, limiting tank sizes to 9- to 10-inch diameters. The data in Table 1-2 illustrates the required backwash rates for five different granular filtering media employed in 10-inch diameter filter units and also the normal service flow rates. Backwash rates for multilayered media filters should be governed by that flow rate necessary to expand the topmost layer of the bed.

Table 1-1
Flow Rate Measurements in US Gallons and Liters

Time to Fill a 5 US Gallon (or 19 liter) Container	Equivalent Flow Rates US Gal./Min.	Liter/Minute
120 seconds	2.5	9.5
60 seconds	5.0	19.0
45 seconds	7.5	28.4
30 seconds	10.0	37.8

Source: Wes Max, Ltd.

Filter bed surface area in a round filter tank can be calculated by multiplying the constant π (pi) (3.1416) by the diameter of the tank in feet squared (diameter feet x diameter feet) and dividing by 4.

Table 1-2
Typical Filter Service Flow Rates vs. Required Backwashing Flow Rates for 10-Inch (25 cm) Diameter Tanks [area 0.49 ft^2] to Achieve 10-20% Bed Expansion

Medium	Minimum Backwash Rate US gpm	L/min.	Service Flow Rate US gpm	L/min.
Sand filter	7.5	28.4	3.0	11.4
Anthracite filter	5.2	19.7	3.0	11.4
Calcite filter	5.3	20.0	2.4	9.0
Activated carbon filter	5.0	19.0	3.0	11.4
Pumicite filter	4.5	17.0	3.0	11.4

TANK-TYPE FILTERS

Most tank-type filters are designed with the "downflow" service pattern: i.e., water in at the top, passes downward through the medium bed, is collected at the bottom, and then directed upward (Figure 1-4) via a riser tube for service. This flow pattern, also called cocurrent, is used in many home water softeners as well. The rate at which a domestic granular media filter can process water is governed by:

- Filter bedface (cross-sectional surface) area "A"
- Bed depth "B"
- Particle sizing of granular medium

Manufacturers rate tank-type sediment filters for service flow based on US gallons per square foot of bed "A" surface area-in other words, the horizontal plane of the bed to the vertical flow of water. As illustrated, the topmost few inches of the medium bed, known as the filtration zone, actually does the bulk of the filtering task. The medium, itself, must be coarse enough to allow some penetration beyond this zone to prevent rapid loss of head[1]

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Figure 1-4 illustrates the physical arrangement of filter segments.

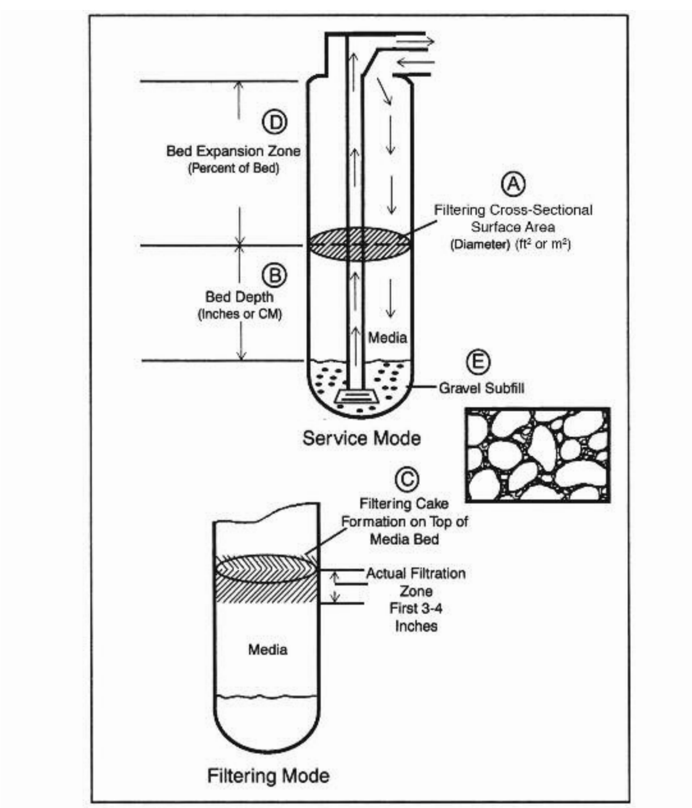
When a filter aid, such as alum, is necessary to enhance filtration ability, the precipitated alum, along with the very fine particulates that are removed, form a sludgelike layer on top of the medium bed. This is sometimes referred to as filter cake ("C"). This sludgelike material creates a thin, very fine layer above the medium, which can then "screen out" organic or other very finely divided undissolved particles from the stream of turbid water. This sludgelike layer is, however, removed during normal backwashing, and until a new layer builds up, the product water may not be up to quality standards.

In iron removal filters of this design, a similar sludge layer condition can be created from precipitated oxidized iron. While the iron cake layer is present, excellent iron-free water can be produced.

BED (BACKWASH) EXPANSION

The bed expansion zone "D" is critical to good filter design as well as to operation, as it provides the means of separating the filtered-out particulate from the medium during the backwash function. The bed expansion zone is incorporated in the engineering design of tank-type filters not only to permit the media (or ion exchanger) to fluidize so entrapped particulates can be removed during backwashing, but also to retain the medium in the vessel itself.

Figure 1-4
Illustration of Service (Filtering) Operation of a Tank-Type Downflow System



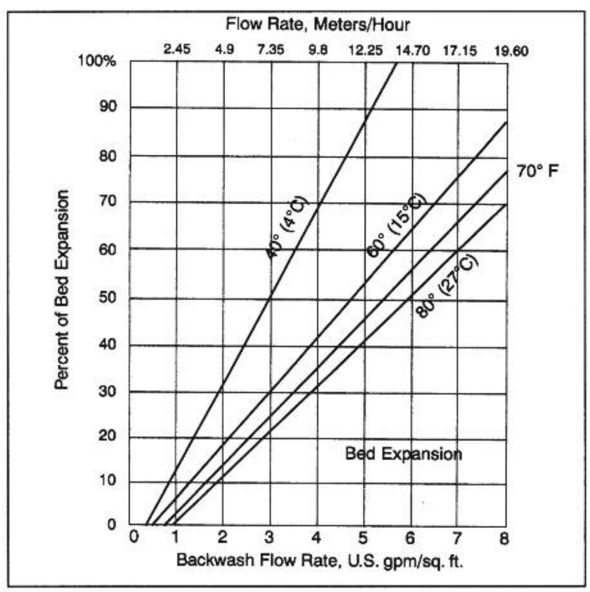
Inadequate backwashing of tank-type filters can lead to the creation within the bed of "mud balls," which occur from the agglomeration of filter medium particles and entrapped sediment. Filter overrun is the chief cause, and the longer the filter operates beyond the regular backwash point, the more the additional pressure exerted on the bed can compact the mud balls. Extended backwashing may not be enough to break up these mud balls, in which case, they can continue to grow[2]. The most common causes of tank-type filter failure of all types (either reactive or inert media) are:

- Inadequate backwash flow rate (pump capacity)
- Too long an interval between backwashing
- Backwashing for too short a time-less than 10 minutes

The degree to which expansion can occur is directly related to the density of the medium itself, the medium particle sizing, and the temperature of the backwashing water. Figure 1-5 illustrates that the colder the backwash water, the greater the expansion of the media bed (at the same US gpm flow)-as water is more viscous (dense) at lower temperatures.

Percent bed expansion to be calculated with the formula % Bed Expansion = $7 \left(\frac{gpm/ft^2}{°C+18}\right)$ [4 - 2.75 (specific gravity of the media)]

Figure 1-5
Example of Water Temperature on Percent of Bed Expansion



With the particular medium shown in Figure 1-5, a 30 percent greater linear expansion takes place at 40°F (4°C) versus 80°F (27°C) water temperature using the same backwashing flow of 4.0 US gpm. The heavier (more dense) the medium, such as sand or calcite, the more limited the percent of bed expansion when compared to, say, granular activated carbon or an ion exchange resin at the same given backwash flow rate. As a general rule, the lighter or lower the density factor,

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the greater the percent of bed expansion that will be required. Table 1-3 provides a better understanding of the density factor of many common filter media when these products are inside a tank, fully wetted.

It is incorrect to look at the specification sheets on various media and use the “bulk density per cubic foot” to determine how much backwash flow will be needed. The fully wetted product with its specific gravity density relative to the density of water (Table 1-3) is what dictates the backwash flow required for each medium for full-bed cleansing and reclassification in each operating cycle.

Again, a strong, steady flow rate is necessary to achieve adequate bed expansion and the cleansing of the filter medium bed itself during each backwash/rinse cycle. Figure 1-6 illustrates the function of the expansion zone “D” and its relationship to the medium bed per se.

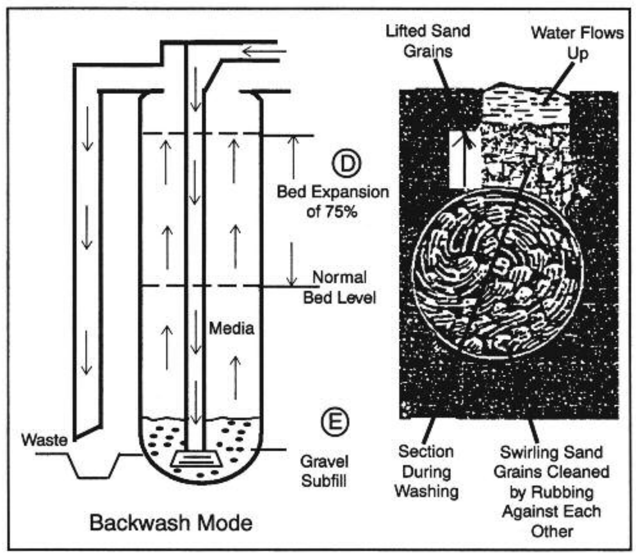
Table 1-3
Comparative Densities of Common Filter Media Products

Product	Effective Size (mm)	Average Bulk Shipping Weight Density (lbs. per cu. ft.)	Absolute Density in Column (Wetted) Operation
Garnet	0.4-0.6	160	3.8
Sand	0.3-0.9	110	2.7
Calicite	0.4-0.6	95	2.6
Manganese Greensand	0.3-0.045	85	2.5
Anthracite	0.7-1.6	56	1.4
Activated Carbon	0.7-0.9	28	1.25
Cation Resin (Na^+)	0.4-0.6	52	1.21
Anion Resin Type I (Cl^-)	0.39-0.47	44	1.10
Water	–	–	1.00

Source: Wes Max, Ltd.

The best backwash and the fullest utilization of a filtering bed can be achieved by using a gravel or other coarse medium subfill under bedding “E” for any of the aforementioned granular filter bed media. The general packing tendency of the irregularly shaped filter media granules thwarts good distribution of the backwash water. The larger void spaces of gravel allow for better lateral distribution, getting more water across the bottom face of the filter media bed more evenly. This, in tum, enables the system to exert the uniform upward thrust for full bed expansion and the elimination of entrapped dirt and particulate.

Figure 1-6
Backwash Expansion of a Tank-Type Medium Filter



DUPLEX FILTERING

As mentioned earlier, the lack of sufficient water flow to properly backflush filter beds is a critical concern. The most common practice to overcome an inadequate backwashing flow rate is to install two smaller identical units (Figure 1-7) operating in a parallel flow pattern. This arrangement is also called a duplex installation[3]. Just about any water processing equipment, such as softeners, filters, or reverse osmosis systems, can be plumbed in the parallel flow pattern.

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Such duplex installations are either two exact models or systems that provide two filter tanks sharing one common master control valve (Figure 1-8). Each of the twin tanks would backwash and rinse down independently, usually at different intervals, quite often sequentially. By using time clock controls or demand-metered equipment, each tank can be cycled in this manner. An advantage of any duplex system is an available continuous flow of filtered (tank A) product water, while the second tank (B) is being recycled.

By the same token, each tank in a duplex filtering system can be backwashed and rinsed down with filtered product water; thus, no added sediment from the raw water gets into the medium bed. Also, using filtered water for recycling shortens the rinse down with little or no bleedoff occurring. Shorter backwash and rinse down time leads to water conservation. However, if oxidized iron is being filtered out, longer times may be necessary for backwashing (15 to 20 minutes) and rinsing (at least 10 minutes).

Figure 1-7
Typical Duplex Filter System

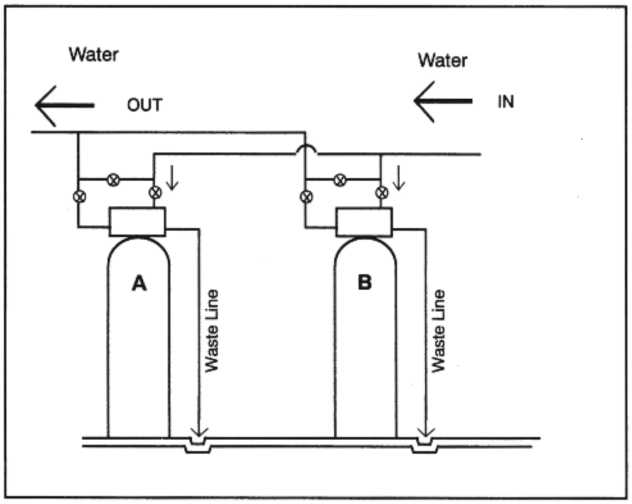
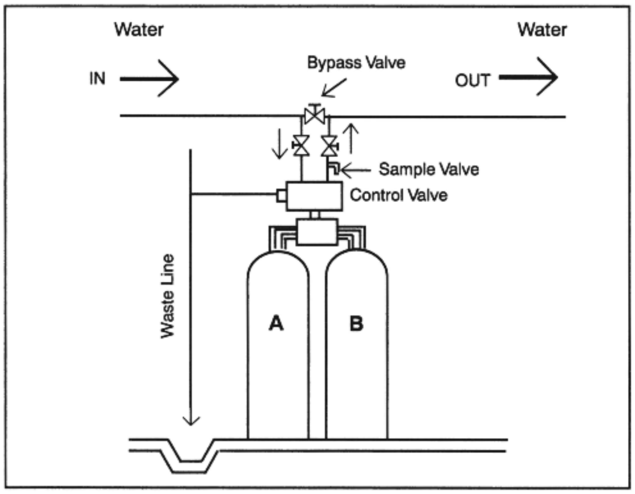


Figure 1-8
Typical Duplex Twin-Filter System



FILTER BED HEIGHT

Recognizing that the first few inches of bed do the major filtration task, many large commercial filter manufacturers began designing filter units with short-bed, squat tanks for sediment filters. This allowed them to stack several in the same floor space using parallel piping schemes. For years, swimming pool filter manufacturers have used 15- to 18-inch sand or anthracite filter medium beds, saving on material and space.

Most of the tank sizes in residential water treatment equipment are based on water softener design needs. Thus, it has been customary for domestic manufacturers to adapt the same size tank for filters and softeners, achieving uniformity in tank inventories. Also, installations in the home that match water softener and filter tanks are more attractive. (From the practical side, residential tank-type filters represent only 5 to 10 percent of the combined water softener and filter production in the United States.)

Residential loose-media sediment filters could be much shorter (15- to 18-inch beds) and still do the filtration task well. Many well water supplies, however, have multiple water contaminants to be corrected, so the deep bed of the chemically reactive loose media system generally is better able to address these needs.

References:
[1] Betz, *Water Handbook,* 8th ed., 1980.
[2] E. Kreusch, personal communication, December 1989.
[3] J. Hunt, "Residential Filters", *WC&P,* June 1992.