Application Advice

Sizing Whole House Softeners and GAC Filters

by C.F. "Chubb" Michaud

"What the customer needs is not zero hardness or zero ppb of organics. If a homeowner is seeing 20 grains of hardness with iron staining, he will be ecstatic to experience 1 grain of hardness (more or less) and no staining."

While there are many factors which contribute to the proper selection and sizing of water filters, the whole house POE filter system seems to have evolved into a "specification" rather than an "application." We hear references to the "typical" whole house unit, generally accepted as a one cubic foot or so system — regardless of the challenge, the need or the size of the house. While this is convenient, it doesn't necessarily make it right. The "one size fits all" approach to POE filtration warrants a closer look.

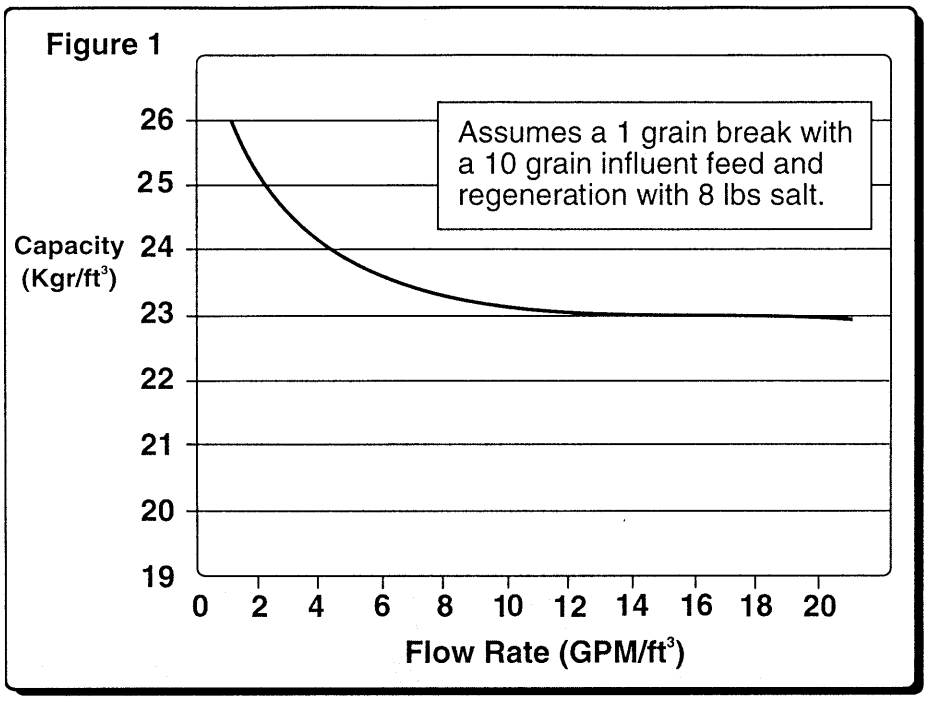
Most household appliances, such as a TV set, a washer and dryer or even a toaster are purchased on the basis of need, suitability and value with a great deal of shopping and comparing involved. Water filters are sold door-to-door, often to people who do not even recognize their need for such a device. They will accept the benefits, once demonstrated, but they have little opportunity to shop. The customer places the choice of the system in the hands of the seller. "Tell me what I need," he says.

Fortunately, what the customer *needs* is not zero hardness or zero ppb of organics. If a homeowner is seeing 20 grains of hardness with iron staining, he will be ecstatic to experience one grain of hardness (more or less) and no staining. If the customer is experiencing 1.5 ppm of chlorine, that customer will be thrilled with 0.15 ppm. If organics make the water the color of tea, the customer may be delighted with a ginger ale hue. All of this means that we have some room for error, however, there are advantages to proper sizing. One is that you may be able to build a smaller unit for a more competitive price. A second is that you may be able to combine systems for a higher sale and profit value. Third, you'll probably sleep better. Always start by telling the customer what is needed, and be prepared to explain and demonstrate the results and enumerate the benefits.

The softener

Softeners can remove 99.5 percent of total hardness with relative ease. How fast can we run them and still remove 98 or 95 percent? The answer is: very fast.

Leakage is a measure of regeneration efficiency and completeness. It is caused by near-zero hardness water (having passed part way through the *"in-situ"* regeneration of the resin during the service cycle.) New or 100 percent-regenerated resin



does not leak. However, one can run so fast that there is not enough time to remove all of the influent hardness. This is called "slippage." At high flows, one can have slippage on top of leakage, particularly on smaller units that are regenerated very quickly.

Since capacities are run to breakthrough, i.e. 10 ppm, resins that are run at very high flows still have capacity. That is, they can still produce a certain gallonage of output before reaching the endpoint breakthrough. Therefore, *maximum* flow rate is more a function of pressure drop than of kinetics. In other words, *a softener is not flow-rate-limited due to volume, it is just plain flow-limited due to surface area (pressure).* A 10-inch cartridge containing 1/40th of a cubic foot of resin, and flowing at 1 gpm (equivalent to 40 gpm per ft³), can still soften water. It may only reduce 15 grains to one grain, and it may immediately be on the breakthrough portion of the run, nonetheless, it can soften water for some moderate level of capacity.

If resin can be run at such flow rates, why not design residential softeners around flow rates of 20 to 30 gpm/ft³ instead of 6 to 8 gpm/ft³? The answer is that *you can*. The problem is one of pressure drop, not kinetics. If water usage is not the issue and salt usage and disposal are not issues, smaller units can offer a good value. If *space* is the issue, i.e., as in RV or mobile homes, softeners can be made in 8-inch by 18-inch or even 6-inch by 18-inch sizes with 1/3 of 1/4 ft³ of resin. If fine mesh resins are used and distribution is built in, even shallower beds will work. At 4 to 5 gpm (for one or two people), good hardness removal with normal pressure drops (due to shallower beds) can be realized with a loss of only 10 to 15 percent of capacity (i.e., 22 to 23Kgr/ft³). (See Figure 1.)

You can take advantage of this by combining multiple (stacked) filters using combinations of GAC and softening or KDF and softening, and still produce a final filter no larger than a normal softener. Figure 2 is equivalent in size to a 10-inch by 54-inch, single-tank system, yet contains a 1 ft³ softener *plus* a 10 gpm dechlorination filter (GAC) and uses only one control valve, shown in Figure 2.

Sizing for efficiency

Table 1 is a work-up of tank sizes approached from a hydraulics (flow rate) point of view. This table shows the relationship between the number of people in a household, the flow needs, the tank area and cubic footage of resin to satisfy softening needs without an undue level of pressure drop. Flow rates are in the range of 6 gpm/ft³ with maximum flow designed not to exceed 15 gpm/ft². Assumptions made were that we used a base flow rate of 2 gpm *plus* 1.5 gpm per person at peak flow, and maximum flow per ft² of tank area did not exceed 15 gpm.

Once the hydraulic design has been established, we then need to calculate the timer setting for each unit. Table 2 shows a relationship between the size of the household and the influent hardness and the number of days per cycle. It assumes a soft water usage of 70 gallons per person per day *plus* a 20 percent reserve. Note that no system

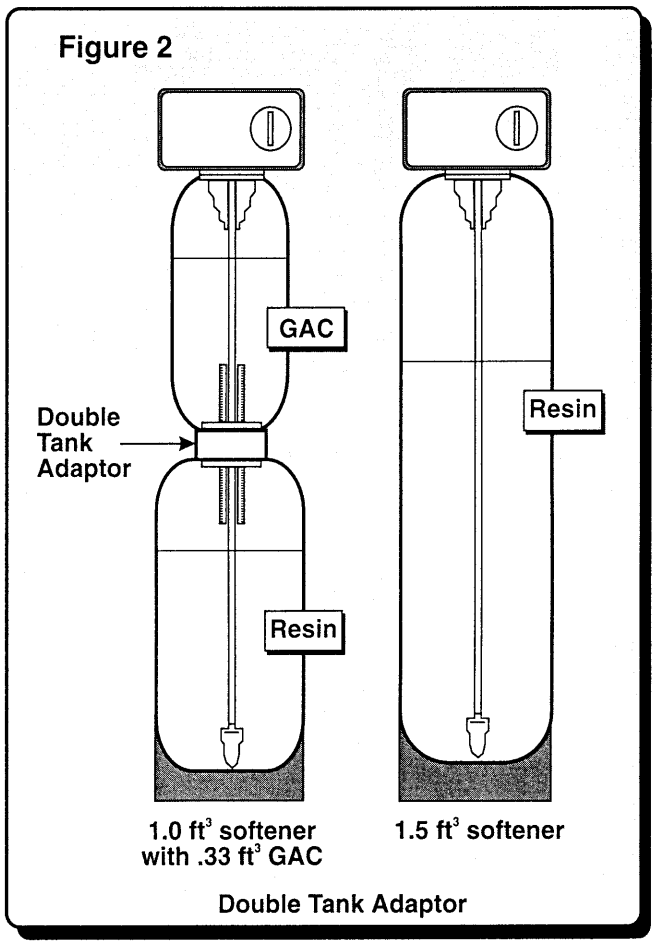


Table 1: Tank Sizing

Number People	Max. Flow	Req'd Area	Tank Dia.	Actual Area	Bed Depth 24"	Bed Depth 30"	Design Use Vol.
2	5.0 gpm	.33 ft³	8 in.	.35 ft²	.70 ft³	.88 ft²	.75 ft²
3	6.5 gpm	.43 ft³	9 in.	.44 ft²	.88 ft³	1.10 ft²	1.00 ft²
4	8.0 gpm	.53 ft³	10 in.	.55 ft²	1.10 ft³	1.40 ft²	1.25 ft²
5	9.5 gpm	.63 ft³	10 in.	.55 ft²	1.10 ft³	1.40 ft²	1.50 ft²
6	11.0 gpm	.73 ft³	12 in.	.78 ft²	1.60 ft³	1.95 ft²	1.75 ft²
7	12.5 gpm	.83 ft³	12 in.	.78 ft²	1.60 ft³	1.95 ft²	2.00 ft²
8	14.0 gpm	.93 ft³	13 in.	.92 ft²	1.84 ft³	2.30 ft²	2.25 ft²

Max Flow = 1.5 gpm/person + 2 gpm and 15 gpm/ft²

is designed for less than three days between regenerations. Also note that iron receives special treatment. Each part of iron is calculated as 3 grains of hardness.

Example: Select a properly sized unit and cycle setting for a five-member household with 16 grains of hardness and 1 ppm of iron.

The unit will be a 10-inch tank with 1.5 ft³ of resin (36 Kgr capacity). The challenge level is 16 + (1 x 3) = 19 gr equivalent. At 70 gpd/person plus a 20 percent reserve, we will need a capacity of 5 x 70 x 19 x 1.2 = 7,980 grains/day. Since our unit has a capacity of 36 Kgr, we have a capacity of 4.5 days (36,000 divided by 7,980). This includes a 20 percent reserve. If the family has two adults and three teenagers, set the unit to regenerate every four days. Otherwise, you may be able to squeeze out five days. Table 2 shows four to five days.

If you determine the daily usage of softened water to be some value other than 70 gpd, use that figure in the above equation. For instance, at 60 gpd: 5 x 60 x 19 x 1.2 = 6,840 grains per day. The setting now becomes every five days. *The key here is to size the unit for hydraulics, then determine the regeneration frequency.*

The GAC filter

Sizing a GAC filter for dechlorination can follow the same rules for hydraulic loading as were used with a softener (Table 1). The variable becomes the unit life (Figure 3) and removal efficiency.

GAC filters should backwash at least once a week for 5 to 10 minutes to reclassify the bed and to remove dirt, carbon fines and gas pockets. Unit size is often limited by the size of the inlet line and subsequent ability to backwash. It takes 10 to

Table 2: Cycle Setting

Number People	Maximum Flow	Tank Dia.	Resin Volume	Calculated Equivalent Influent Hardness (grains) 10	12	14	16	18	20	22	24	26	28	30
2	5.0 gpm	8 in.	.75 ft³	10	9	8	7	6	5	5	4	4	4	3
3	6.5 gpm	9 in.	1.00 ft³	9	8	7	6	5	5	4	4	4	3	3
4	8.0 gpm	10 in.	1.25 ft³	9	7	6	5	5	4	4	4	3	3	3
5	9.5 gpm	10 in.	1.50 ft³	8	7	6	5	5	4	4	4	3	3	3
6	11.0 gpm	12 in.	1.75 ft³	8	7	6	5	5	4	4	3	3	3	3
7	12.5 gpm	12 in.	2.00 ft³	8	7	6	5	5	4	4	3	3	3	3
8	14.0 gpm	13 in.	2.25 ft³	8	7	6	5	4	4	4	3	3	3	3

Number of Days at 8 lbs. Salt

Max Flow = 1.5 gpm/person + 2 gpm and 15 gpm/ft². Add 3 grains hardness per pm of Iron.

12 gpm/ft² to backwash GAC. A 10-inch tank requires 6 gpm for typical 12 x 40 mesh coal carbons and nearly 7 gpm for 12 x 30 coconut shell. Vessels larger than 10-inch should only go onto 1-inch inlet lines and use 1.050-inch internals. A 12-inch tank will require 8 to 9 gpm for backwash.

Make sure adequate backwash flow is available before using a 14-inch or 16-inch tank. Good water pressure on a 1-inch line will handle it. Use two smaller vessels with alternating backwashes if line pressure is under 40 psi.

Example: Determine the capacity and frequency of changeout of an 8-inch tank with .33 ft³ of GAC for a family of two.

From Table 1, we see that the planned flow maximum is 5 gpm. That equals 15 gpm/ft³ flow which, from Figure 3, indicates a capacity of around 300,000 gallons/ft³. Since we have only .33 ft³ of GAC, our expected yield is 100,000 gallons (which should equal two years for a two-person household.)

Please note that the above reference is for dechlorination only and should not be used to size GAC units for the removal of toxic organics, pesticides, etc. Such systems should be large and freestanding with retention times (EBCT) of 5 to 10 minutes. Chlorine is quite easily removed by a good-quality GAC. Again, note that the trick is not to restrict the flow to too small a diameter system.

It is a good practice to back up a GAC filter with a 20 micron sediment filter downstream. A 20-inch slimline (2.5-inch) cartridge will work fine and have less pressure drop than a 10-inch long 4.5-inch diameter unit.

Conclusions

The sizing of a whole house filter is as individual as the family for which it is designed. While a younger family's needs will change over time, as will the water quality (hardness), the only variable that need be considered is the frequency of regeneration if you get the hydraulics right at the start. Anticipate the family's needs 10 years down the road.

The equipment being built today will last a long time. No one intends to wear out a home softener. This author's home softener is 25 years old and doing well. When I purchased this unit in 1970, my three children were pre-schoolers. It is a one-cubic-foot unit and we ran out of soft water a lot when they were teenagers, even though it was set to regenerate every other night.

About the Author

Chubb Michaud is president of Systematix Co. in Brea, Calif., and has been a frequent contributor of technical information and articles on various industrial, commercial and domestic filtration applications. He has been associated with fluid processing and water filtration for most of his 30 years in field service.❑

Figure 3