Eductors, also called injectors, work on the Venturi principle. They are fluid pumps with no moving parts. Flow through the device is restricted, creating a high-pressure area. Fluid then explodes through an orifice, creating a low-pressure area that creates suction. That suction draws chemicals or slurries into the device, mixes it with the feedwater and pushes it downstream.

Selecting an eductor

The Venturi is a tee-shaped device that passes fluid through a restricting nozzle (see Figure 9), increasing its flow velocity and pressure. Fluid then passes into an expansion cone (or throat) to create suction on a third leg. Both the flowrate through the nozzle and the amount of draw are determined by the design of the eductor. Fortunately, we don’t have to design this eductor but merely do the calculations and select the proper one. The calculations are a bit complex, requiring one to determine the draw rate of the device that will match your needs based on an unknown feed pressure and an unknown back pressure. These determine the efficiency of the eductor and ultimately allow the user to determine how much, how fast and how long.

To select the right eductor, one must assume certain things that generally are not known at the time of the design. These include the actual feed pressure available to the eductor at the time of use. This is not the same as the static line pressure when everything is shut down; it will depend a lot on where else water is being used at the time of regeneration and whether the parallel on-line unit is used continuously or intermittently. Back pressure will depend on where the waste stream is directed. Is it on the second floor? Is it in the basement? Back pressure may vary depending on how full the waste tank is. Fluid density, the only other factor in the calculation, is known. Don’t assume that all brine is saturated, however, and at full density. In all honesty, I have to tell you that selecting the proper eductor may take a couple of tries. Plumb them in with unions on all sides so they can be easily replaced after start-up.

In determining the proper eductor, it will pay to visit the job site and determine dynamic water pressures and the whereabouts of the waste destination to help determine the back-pressure component for the calculations. There are many good designs out there and each one has a different performance curve. Total regenerant flow and slow rinse are based on eductor characteristics. Total flow is nozzle flow plus the draw rate; slow rinse is the nozzle flow only. Use a check valve in the chemical feed line to ensure that water is not blown back into the chemical tank in the event of a sudden increase in back pressure. This is critical when setting up DI systems because water added to acid or caustic can create a violent heat reaction, thereby causing water to boil and spatter the chemical.

Eductors used for brine (softeners and chloride form anion) and chemical for DI will draw and dilute to about 40 percent of the bulk solution concentration (3:2 dilution). Saturated brine is about 25 percent and is diluted to about 10 percent for regeneration. Hydrochloric acid (HCl) used in DI cation, however, is generally delivered at 31 percent and used at five to seven percent (6:1 dilution). Caustic comes in as a 50-percent NaOH solution and used at four to five percent (10:1 dilution). I usually pick an eductor that is slightly larger than needed and put metering ball valves on the feed line to control pressure and the regenerant line to control rate of draw. It is rare that the selected eductor will operate flat out with available line pressure and subsequent back pressure, and provide just the right dilution at just the right flowrate. Yes, it happens. One can manipulate these flows with limit stop valves or ball valves, however, allowing the user to dial in the proper flows.

Figure 10 shows the location of the eductor in a typical regenerable ion exchange system. During regeneration, water is routed through the regeneration valve with the inlet valve closed. This activates the eductor, which draws chemical through the draw valve. Chemical is diluted and mixed in the ensuing pipe and exits through the rinse valve. When using automatic valves and a system controller, valves can be installed with limit stops, which allows them to be used for flow control. Alternately, a manual ball valve can be put in-line ahead of the automatic valve and be used as a rate set. Once set, they can be left as is with the flow isolation being controlled by the automatic valves.

Automatic control valves

The common automatic valves used for softeners and
dealakers have built-in eductors and are generally designed with a 3:2 dilution factor. In addition, these eductors are easily accessible and can be readily changed on-site if the calculations are off. For the most part, these eductor systems carry numbers that correspond to a certain size tank with a given amount of media. The user must simply look up the tank size and make the proper selection. The external eductors used for larger softening systems and DI operations are a little less forgiving and require a higher level of expertise in their selection.

**External eductors**

To size an eductor, one has to make initial assumptions for feed pressure and back pressure. I start with 60-psi feed and 5-psi back pressure but a site inspection can verify this. One vendor's convenient sizing chart gives nozzle flows and draw factors for various nozzles and throats that are fabricated to accept threaded connectors in 0.5-, 0.75-, 1.0-, 1.5- and 2.0-inch FNPT. These eductors also dilute on a 3:2 ratio, which is ideal for softeners but will require additional throttling valves for DI operation. First, determine the efficiency of the eductor with a feed and back pressure (from Figure 11).

For sizing a 10-ft³ softener we will assume 60-psi feed and 5-psi back pressure. We read 75-percent efficiency from Figure 10. We know from experience that a 10-ft³ softener will have a regeneration flow of 0.25 to 0.5 gpm/ft³. This is 2.5 to 5 gpm. Then we select an eductor with a nozzle flowrate of approximately 60 percent of our high-regeneration flowrate of 5 gpm (~3.0 gpm). From the nozzle flowrate chart, using 60-psi feed, that’s a Model 541-2 with a 3.1-gpm nozzle flow and a draw factor of 1.15 (see Table 5). This particular eductor has a 3.2 dilution and we need 3 to 5 gpm total diluted regenerant brine flow. Using Equation 3, we can calculate the draw rate as:

**Equation 3.**

\[
\text{Draw rate} = A \times C \times D / B
\]

Where:
- A = nozzle flowrate = 3.1
- B = specific gravity of regenerant = 1.2 (for brine)
- C = draw factor = 1.15
- D = efficiency factor = 0.75

*Specific gravity for 31% HCl = 1.14, 50% NaOH = 1.52 and 20% H₂SO₄ = 1.13

If brine discharge is located some distance away or is elevated, there will be a higher back pressure. Do not undersize the brine discharge line. The higher the back pressure, the lower the efficiency and the more difficult it will be to control.

Using the above values, the draw rate = 3.1 x 1.15 x .75/1.2 = 2.23 gpm. Total flow = 3.1 (nozzle) + 2.2 (draw) = 5.3 gpm or 0.53 gpm/cu ft for a 10-cubic-foot system. Regenerant brine will be 10.1 percent. Since the 10 cu. ft. will require 80 pounds of NaCl (8 lbs/cu ft) and saturated brine contains 2.67 lb/gallon (charts not included here), we can calculate that we will need to draw (80/2.67 =) 30 gallons of brine. At a draw rate of 2.23 gpm, we will set the initial brine draw at (30/2.23 =) 13.64 minutes. This is a little short in retention time. If we have a ball valve on the eductor feed line, we can throttle back to reduce the feed pressure and lengthen the draw time. Using the same vendor references, here are the values for the injectors on either side, plus the one selected:

**Model 541-1.**
- Nozzle flow = 1.80 gpm
- Draw factor = 1.15
- Efficiency = 75 percent
- Draw rate = (1.80)(1.15)(.75)/(1.2) = 1.29 gpm
- Total flow = 1.8 + 1.29 = 3.1 gpm
- Draw time = 30 gal/1.29 gpm = 23.25 minutes (good)
- Flow/ft³ = 3.1/10 = 0.31 gpm/ft³

**Model 541-2. (from above)**
- Nozzle flow = 3.1 gpm
- Draw factor = 1.15
- Efficiency = 75 percent
- Draw rate = (3.1)(1.15)(.75)/(1.2) = 2.2 gpm
- Total flow = 3.1 + 2.2 = 5.3 gpm
- Draw time = 30/2.2 = 13.64 minutes (short)
- Flow/ft³ = 5.3/10 = 0.53 gpm/ft³

**Model 541-3.**
- Nozzle flow = 4.90 gpm; Draw factor = 1.15
- Efficiency = 75 percent
Draw rate = \((4.90)(1.15)(.75)/(1.2)\) = 3.52 gpm
Total flow = 4.90 + 3.52 = 8.4 gpm
Draw time = 30 gal/3.52 gpm = 8.5 minutes (too short)
Flow/ft\(^3\) = 8.4/10 = 0.84 gpm/ft\(^3\)

Of the three, Model 541-1 appears to be the best with a flow of 0.3 gpm/ft\(^3\) and 23-minute contact time. Let’s see what the numbers look like if we drop the pressure with a throttling valve, just to see if we have a no-go limitation should the pressure drop (which might necessitate a booster pump). At 50-psi feed with 5-psi back pressure, our efficiency drops to 63 percent. Plugging this value into our calculation for Model 541-1, we have:

Nozzle flow = 1.7 gpm, Draw factor = 1.25, Efficiency = 0.63
Draw rate = \((1.7)(1.25)(0.63)/(1.2)\) = 1.1 gpm
Total flow = 1.7 + 1.1 = 2.8 gpm
Draw time = 30/1.1 = 27.27 minutes (better)
Flow/ft\(^3\) = 2.8/10 = 0.28 gpm/ft\(^3\)

And at 40 psi, our efficiency drops to 51 percent:
Nozzle flow = 1.5 gpm; Draw factor = 1.26; Efficiency = 0.51
Draw rate + \((1.5)(1.26)(0.51)/1.2\) = 1.16 gpm
Total flow = 1.5 + 1.16 = 2.6 gpm
Draw time = 30/1.16 = 25.86 minutes (still okay)
Flow/ft\(^3\) = 2.6 gpm/10 ft\(^3\) = 0.26 gpm/ft\(^3\)

It would appear that selection of the Model 541-1 eductor gives the contact time needed with an appropriate flowrate and is not sensitive to incoming pressure. It does involve a little trial and error but it’s worth the time and effort, and it improves the success rate by 1,000 percent. All eductors use the same logic and principles in calculating draws and dilutions. Most OEMs will do this calculation for end users when they buy the equipment. While one may not wish to take on this responsibility, it helps to have the understanding.

**Summary**

Every aspect of hydraulic design must be factored in to get good cleaning during backwash and optimized distribution during service and regeneration. In addition, adequate pre-planning must be done to make sure pipe sizes are sufficient to handle the total system flow demands. There are minimum flows that must be obtained during regeneration. Too low a flow creates poor distribution and channeling (more on this in Part 8). Excessive flows do not permit enough time for a proper cleaning. Target values are 0.25 to 0.50 gpm/ft\(^3\). Take the time to do the math. A properly sized eductor allows leeway in both flow and feed pressure.

**References**

10. AquaMatic Operations Manual/Eductors 540 Series, Pentair Corporation, Rockford, IL.

**About the author**

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