

Venturi Calculations

Our team decided to use a Venturi Pump/ Nozzle to inject the finished Biochar solution into the main flow line of the Clean Water Machine sand filtration system. Venturi injectors had previously been discussed as a possible volumetric metering solution, since they function like nozzles and require no moving parts to pressurize the flow, while allowing for precise flow rate alterations. This idea was vetoed for metering use because venturi injectors rely on semi-constant fluid viscosity to accurately adjust mass flow rate, but the biochar was proven to mix inconsistently into the water, creating a variable-viscosity solution, which nullified the ability to calibrate and dose biochar amounts in solution precisely (within our tolerances). The venturi injector idea was reevaluated later due to its capability of fulfilling the pressurizing role of a pump without the areas of possible wear and failure from biochar abrasion (impellers, seals, etc). In the revisited function, instead of accurately metering the flow, it was only needed to pressurize the outlet of the by-pass stream for our system to match/ exceed the main-line pressure of the Clean Water Machine, making it possible to forego a pump and keep the solution moving. This was agreed upon as the best course of action, and a venturi injector was specified.

Calculations:

- We were given a desired flow rate (6 GPM minimum to 12 GPM maximum) and system pressure (15 to 20 psig), so Standard Bernoulli's Equation (neglecting tubing/ hose friction factor since it was a quick estimate), as well as Volumetric Flow Rate (Q), was used to calculate to required pressure inputs for the venturi injector with both a ¼ inch and ¾ inch tube.

$$\frac{(P_2 - P_1)}{\gamma} + \frac{(V_2^2 - V_1^2)}{2g} + (z_2 - z_1) = 0$$

$$Q = V(A)$$

Where P_1 is the pressure within the inlet hose, P_2 is the pressure within the mixing tank (atmospheric: 0 psig), γ is the specific weight of water (gamma), V_1 is the inlet velocity for the mixing tank upstream from the venturi suction, V_2 is the outlet velocity of the mixing tank (and inlet of venturi injector suction), g is the gravitational constant, z_1 is the inlet height in the tank, and z_2 is the outlet height of the tank.

Limitations:

- No more than 5 psi taken from 20 psig pressurized main line.
- Must inject back into main line at 12 psig or greater.
- Assume 2 psig is drained by mixing tank line and 18 psig inserts directly to venturi inlet. Also, flow rate into mixing tank is approximately 1 gal/min (.0022 ft³/s).

$$V_1 = \frac{Q_1}{A_1} = \frac{(.0022 \text{ (ft}^3\text{/s)})}{A}$$

Where A= 0.000341 ft² for ¼ inch hose and A= 0.003068 ft² for ¾ inch.

Using the same procedure and equations to solve for the outlet conditions yields:

Flow Rate into Tank:	Flow Rate Out of Tank:
Q ₁ : 1 gal/min (Same for ¼ and ¾ inch)	Q _{2-1/4} : 3.177 gal/min Q _{2-3/4} : 3.018 gal/min
V _{1-1/4} : 6.536 ft/s	V _{2-1/4} : 20.765 ft/s
V _{1-3/4} : 0.726 ft/s	V _{2-3/4} : 19.723 ft/s

Given the values found above (converting gal/min to gal/hr) and the limitations on the system, the venturi specification parameters were as follows:

Injector Inlet Pressure Range: 15 to 20 psig
 Injector Outlet Pressure Range: 12 to 15 psig
 Motive Flow: 6 to 12 GPM (gal/min)
 Water Suction: 60 to 180 GPH (gal/hr) or 1 to 3 gal/min

Using the above values in the Manufacturer's Table shown below, the 1078-03 injector model was chosen as the best fit for our system.

Injector Performance Table

Water Suction Capacity														REV 2014
Operating Pressure PSIG		Model 584 ½" & ¾" Threads		Model 684 ¾" Threads		Model 878-03 1" Threads		Model 885X-03 1" Threads		Model 1078-03 1" Threads		Model 1583 1½" Threads		
Injector INLET	Injector OUTLET	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	Motive Flow GPM	Water Suction GPH	
15	0	3.6	28.1	6.1	26.1	6.3	87.3	6.2	135	9.5	101	18.6	225	
	5		27.9		26.1		62.1		83.1		79.9		163	
	7		28.0		25.0		45.4		58.0		64.6		124	
	10		13.9		12.8		23.6		19.1		34.2		86.5	
	12		11.0		7.0		7.2		11.0		16.9		14.5	