Simplified sparger design

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☐ In designing a sparger, the objective is to get uniform flow distribution along the length of the pipe. Usually, the length and diameter of the pipe are given, and the design focuses on the number and diameter of the holes. The figure shows a typical situation.

Perry's[1] offers a verbal rule-of-thumb for the design: "The ratios of kinetic energy in the inlet stream to pressure drop across the outlet hole and of friction loss in the pipe to pressure drop across the outlet hole should be equal to or less than one-tenth." When this rule is satisfied, the expected maldistribution in the flow is less than 5%.

These constraints can be compactly restated:

$$\alpha\frac{\rho\bar{V}_p^2/2}{\Delta P_o} \leq 0.1 \qquad \frac{\Delta P_p}{\Delta P_o} \leq 0.1 \qquad (1,2)$$

where the correction factor α is about 1.05 for turbulent flow.

To convert (1) to a useful form, we first calculate ΔP_o using a relationship for turbulent flow through a sharp-edged orifice (with an A_o/A_p ratio between 0.05 and 0.70)[2]:

$$\Delta P_o \approx 2.6\rho\frac{\bar{V}_o^2}{2}\left[1 - \left(\frac{A_o}{A_p}\right)^2\right] \qquad (3)$$

By continuity, we know that $A_o\bar{V}_oN = A_p\bar{V}_p$. Using this relationship and (3), we can convert (1) to an expression for orifice diameter:

$$D_o \leq D_p/(1 + 4.04N^2)^{1/4} \qquad (4)$$

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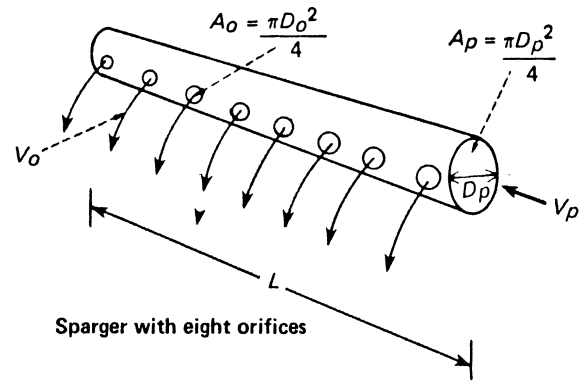

Sparger with eight orifices

Since N is generally large, this reduces further to a simple constraint:

$$D_o \leq 0.7D_p/\sqrt{N} \qquad (5)$$

Nomenclature

A_o = Area of one orifice
A_p = Cross-sectional area of pipe
D_o = Diameter of each orifice
D_p = Diameter of pipe
L = Length of pipe
N = Number of orifices
ΔP_o = Pressure drop across each orifice
ΔP_p = Pressure drop in pipe caused by friction
$\bar{V}_o$ = Average velocity of fluid leaving orifice
$\bar{V}_p$ = Average inlet velocity of fluid entering pipe
ρ = Fluid density

To convert (2), we can estimate the friction loss in the pipe as approximately one velocity head per 150 pipe diameters[1]:

$$\Delta P_p \approx \frac{L}{150D_p}\rho\frac{\bar{V}_p^2}{2} \qquad (6)$$

Combining this with (2) and (3), we get the other constraint:

$$D_o \leq D_p/\left(1 + \frac{LN^2}{39D_p}\right)^{1/4} \qquad (7)$$

When the L/D_p ratio is less than 150, (5) is the only constraint that need be considered.

Example: Determine the design constraint for a 5-ft-long, 2-in.-dia. sparger used to distribute water at 50 gal/min. Solution: The Reynolds number for flow at the inlet is over 5,000; thus, the flow is turbulent, and we can use equations (5) and (7). Since $L/D_p = 30$, (5) is the appropriate constraint:

$$D_o \leq 0.7(2 \text{ in.})/\sqrt{N}$$

If we want to drill 20 holes, then the maximum hole diameter should be 0.32 in. In practice, half of the maximum diameter is recommended.

References

1. Perry, R. H., and Chilton, C. H., ed., "Chemical Engineers' Handbook," 5th ed., McGraw-Hill, New York, 1973.
2. Denn, M. M., "Process Fluid Mechanics," Prentice-Hall, Englewood Cliffs, N.J., 1980.