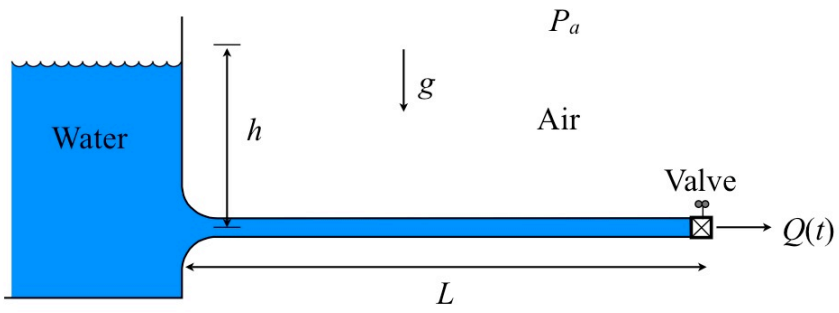
MIT Department of Mechanical Engineering
2.25 Advanced Fluid Mechanics

Problem 4.25
This problem is from "Advanced Fluid Mechanics Problems" by A.H. Shapiro and A.A. Sonin



Water flows from a large reservoir through a very long pipe under constant head h. When the valve is slowly closed, the head h remains constant, but the volume flow rate is reduced.

a) Neglecting friction and compressibility of the water, demonstrate that the gage pressure just upstream of the valve at any instant during the closure period is given approximately by

$$p = \rho\left(gh - \frac{Q^2}{2A^2} - \frac{L}{A}\frac{dQ}{dt}\right) \tag{4.25a}$$

where A is the cross-sectional area of the pipe.

b) Suppose the "valve" is a short, frictionless nozzle with variable exit area $A_e(t)$. At $t < 0$, prior to valve actuation, a steady flow takes place with $A_e = A$. It is desired to program the valve closure such that the volume flow rate decreases linearly in time from its initial steady-state value to zero in a period of τ. Show that this requires that $A_e(t)$ be programmed such that

$$\frac{A_e(t)}{A} = \left(1 - \frac{t}{\tau}\right)\left[1 + \left(\frac{L}{\tau}\right)\left(\frac{2}{gh}\right)^{\frac{1}{2}}\right]^{-\frac{1}{2}} \tag{4.25b}$$

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Fall 2013

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