A vessel containing saturated liquid water at 1000 psia discharges to atmosphere through a horizontal line. Show how you would determine the initial mass flux through the discharge line (i.e. before the vessel has a chance to depressurize significantly). Give all relevant equations. You may assume the flow is isentropic (i.e. no frictional losses) such that only acceleration losses are significant.

SOLUTION

The acceleration loss in the pipe is given by

\[
G^2 \left[ \frac{(1-x)^2}{\rho_f} + \frac{x^2}{\rho_g} \right] - u_o = (P_o - P_T)
\]

where the subscript \( T \) denotes conditions at the throat or discharge point and \( o \) denotes the reservoir or stagnation conditions. From the chart of critical pressure versus stagnation pressure for saturated liquid water, the critical pressure at 1000 psia is approximately 550 psia, implying the flow is choked at the discharge point. The mass flux is then determined by

\[
G^2 = \frac{(P_o - P_T)}{\left[ \frac{(1-x)^2}{\rho_f} + \frac{x^2}{\rho_g} \right] - u_o}
\]

where the throat conditions are taken at the critical pressure. The stagnation conditions are given as a saturated liquid at 1000 psia and are therefore known. Since the flow can be assumed isentropic, the quality at the discharge point is given by

\[
x_T = \frac{s_o - s_f}{s_{fg}} p_f
\]

The void fraction at the discharge point can be obtained from the Fundamental Void-Quality-Slip relation

\[
\alpha = \frac{1}{1 + \left( \frac{1-x}{x} \right) \left( \frac{u_f}{u_g} \right) S}
\]

where the slip ratio is given by the Moody model

\[
S = \frac{u_g}{u_f}
\]