Calculating flow out of an open pipe using Bernoulli, Darcy-Weisbach

Bernoulli's Equation, solve for V2 (ignoring height change component)

$$P_1+\frac{1}{2}\cdot\rho\cdot{v_1}^2=P_2+\frac{1}{2}\cdot\rho\cdot{v_2}^2\xrightarrow[]{\substack{solve,v_2\\assume,\rho>0}}\begin{bmatrix}\dfrac{\sqrt{\rho\cdot{v_1}^2+2\cdot P_1-2\cdot P_2}}{\sqrt{\rho}}\\-\dfrac{\sqrt{\rho\cdot{v_1}^2+2\cdot P_1-2\cdot P_2}}{\sqrt{\rho}}\end{bmatrix}$$

Flow Parameters

$\rho_{water}:=1000\ \frac{kg}{m^3}$ *Water Density*

$v_1:=0\ \frac{m}{s}$ *Initial Velocity*

$P_0:=5\ bar$ *Pressure at start of pipe*

$P_1:=1.33\ bar$ *Pressure at pipe exit*

$P_2:=1\ atm$ *Atmospheric Pressure*

$C_D:=0.7$ *Discharge Coefficient*

$D_{orifice}:=15\ mm$ *Orifice Diameter*

$A_{orifice}:=\frac{\pi\cdot{D_{orifice}}^2}{4}=\left(1.767\cdot10^{-4}\right)\ m^2$ *Calculate Pipe Exit Area*

Calculate discharge flow velocity at pipe exit (P.1 - P.2)

$v_2:=C_D\cdot\frac{\sqrt{\rho_{water}\cdot{v_1}^2+2\cdot P_1-2\cdot P_2}}{\sqrt{\rho_{water}}}=5.571\ \frac{m}{s}$ *Calculate v_2 based on parameters (takes into account discharge coefficient)*

$m_{dot}:=v_2\cdot A_{orifice}=3.544\ \frac{m^3}{hr}$ *Calculate m_{dot} based on flow rate*

Estimate pipe head loss (P.0 - P.1):

Darcy–Weisbach equation:

$$\frac{\Delta P}{L} = f_D \cdot \frac{\rho_{fluid}}{2} \cdot \frac{{v_{avg}}^2}{D} \xrightarrow{solve,\Delta P} \frac{L \cdot f_D \cdot {v_{avg}}^2 \cdot \rho_{fluid}}{2 \cdot D}$$

Pipe flow parameters:

$$L := 20\ m$$

$$D := D_{orifice}$$

$$\nu_{water} := 1.052 \cdot 10^{-5}\ \frac{ft^2}{s} = \left(9.773 \cdot 10^{-7}\right)\ \frac{m^2}{s}$$

$$Re\left(v_{avg}\right) := \frac{v_{avg} \cdot D}{\nu_{water}} \qquad Re\left(v_2\right) = 8.551 \cdot 10^4$$

$f_D := 0.018$ *f_D looked up in chart in EIT manual, smooth pipe, Re = 8.5x10^4*

$$\rho_{fluid} := \rho_{water}$$

Solve for pressure drop:

$$\Delta P\left(v_{avg}\right) := \frac{L \cdot f_D \cdot {v_{avg}}^2 \cdot \rho_{fluid}}{2 \cdot D}$$

$$\Delta P_{itr} := \Delta P\left(v_2\right) = 3.725\ bar$$

$$\frac{\Delta P_{itr} + P_1}{P_0} = 1.011$$ *Iterate P_1 and lookup "f" until in chart until ($P_1 + \Delta P = P_0$)*

$$\Delta P_{itr} + P_1 = 5.055\ bar$$ *Sum of P_1* and *ΔP is close to original pressure of 5 bar*