Solutions to Quiz II

Note: In this document, I have focused on common errors rather than giving detailed solution. Text in SMALL CAPS represents common errors I noticed in your solutions. For detailed solution, please refer to solutions to quiz 1. This quiz is out of 10.

- Niket

Problem 1 DP Cell Problem

Problem 1-a Sizing of the cell

Here, you are asked to size the orifice such that a maximum flow rate of 100 gal/min can be measured using a DP cell having range 0-3 psi, USING THE FULL RANGE. Hence, $\Delta P_{max} = 3psi$. Substituting values in the orifice equation provided (USE APPROPRIATE UNITS), we get

$$\frac{100\ gal}{min}\left|\frac{1\ min}{60\ sec}\right|\frac{1\ ft^3}{7.481\ gal}\left|\frac{[12\ in]^3}{[1\ ft]^3}\right. = \frac{0.6A_2}{\sqrt{1-\frac{A_2^2}{7.393^2}}}\sqrt{2\frac{32.2\ lb_m\ ft}{lb_f\ sec^2}\left|\frac{ft^3}{62.4\ lb_m}\right|\frac{3\ lb_f}{in^2}\left|\frac{[12\ in]^4}{ft^4}\right.}$$

$$385.0\frac{in^3}{sec} = \frac{A_2}{\sqrt{1-\frac{A_2^2}{7.393^2}}}\cdot 152\frac{in}{sec}$$

AGAIN, BE CAREFUL OF THE UNITS YOU USE. There are a couple of students who used "mixed units" but were careful enough to convert them to consistent units before solving for A_2. But most often, you need to convert ALL THE TERMS into either in or ft. Similarly, use either min or sec consistently.

ANOTHER ERROR WAS IN EVALUATING THE TERM INSIDE THE SQUARE ROOT.

$$\text{Units of}\quad \frac{2g_c}{\rho}\quad\text{are}\quad \frac{lb_m\ ft}{lb_f\ sec}\cdot\frac{ft^3}{lb_m} \equiv \frac{ft^{\mathbf{4}}}{lb_f\ sec}$$

ALSO, $psi = lb/in^2$.

Solving the equation, we get $A_2 = 2.4\ in^2 = 0.0167\ ft^2$.

Problem 1-b

$\beta = A_2/A_1 = 0.32$, which lies in the range 0.2 to 0.7. The maximum pressure drop across the DP cell is 3% of the total line pressure. Hence the design is **acceptable**.

Problem 1-c Electric signal for square root extraction

Problem 1-d Square root extraction is not used

Irrespective of square root or linear extraction, the correlation between ΔP and Q remains the same. Square root extraction refers to conversion of pressure signal to electrical signal.

The flow rate is proportional to the square root of the pressure drop. Hence, if square root extraction is used, the electric signal in mA will be linearly proportional to the flow rate. Hence, more often than not, square root extraction is used in practice.

Noting that $Q \propto \sqrt{\Delta P}$, we obtain ΔP for $Q = 60\ gpm$. You can verify that for this problem, $\Delta p = 1.08\ psi$. Remember, this is true for both **1-c** and **1-d**.

1-c: If square root extraction is used,

$$mA = 4 + \frac{16}{\sqrt{3}}\sqrt{\Delta P} = 4 + 16 \times \sqrt{\frac{1.08}{3}}$$

Hence the signal will be 13.6 mA.

1-d: If square root extraction is NOT used, the signal is proportional to the pressure drop. Hence, as above, the signal will be $4 + 16 \times \frac{1.08}{3}$, which is 9.76 mA.

Problem 1-e Undersized orifice

Now, we have $A_2^{new} = 0.7 A_2$. Also, A_1 remains unchanged and $\beta^{new} = 0.7\beta$. Thus, we have

$$\frac{Q^{new}}{Q} = \frac{A_2^{new}}{\sqrt{1 - [\beta^{new}]^2}} \frac{\sqrt{1 - \beta^2}}{A_2}$$

Solving, we obtain $Q^{new} = 68\ gal/min$.

Some of you incorrectly considered $[\beta^{new}]^2 = 0.7[\beta]^2$. Appropriate solution is

$$[\beta^{new}]^2 = [0.7\beta]^2 = 0.49[\beta]^2$$

.