EE407 Process Control
Experiment 3

1. From conservation law

$$q_in(t) - q_{out}(t) = \frac{d(Volume)}{dt}$$

$$q_in(t) - q_{out}(t) = A\frac{dh(t)}{dt}$$

$$\boxed{\frac{dh(t)}{dt} + \frac{1}{A}\frac{h(t)}{R} = \frac{1}{A}q_in(t)}$$

2. Taking the Laplace Transform of the both side

$$[s + \frac{1}{AR}]\ H(s) = \frac{1}{A}Q_i(s)$$

$$\boxed{G(s) = \frac{H(s)}{Q_i(s)} = \frac{AR}{A(sAR+1)}}$$

3. The block diagram of the Figure 5 from Preliminary Work can be seen at *Figure 1* while of the Figure 6 from Preliminary Work can be seen at *Figure 2*.

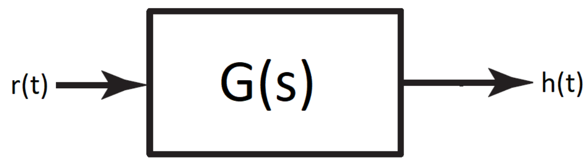

Figure 1: Block Diagram of the Open-Loop System

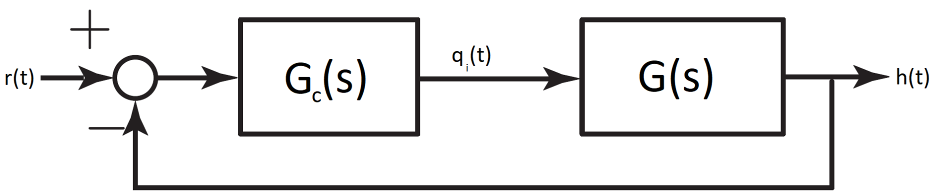

Figure 2: Block Diagram of the Closed-Loop System

General closed loop transfer function of the closed-loop system can be found to be as;

$$G_{CL}(s) = \frac{G_c(s)G(s)}{1 + G_c(s)G(s)}$$

(a)

$$G_c(s) = KL^{-1}$$

$$G_{CL}(s) = \frac{(KL^{-1})(\frac{AR}{A(sAR+1)})}{1 + (KL^{-1})(\frac{AR}{A(sAR+1)})} = \frac{ARKL^{-1}}{A(sAR+1) + ARKL^{-1}}$$

$$\boxed{G_{CL}(s) = \frac{ARKL^{-1}}{sA^2R + A + ARKL^{-1}}}$$

(b)

$$G_c(s) = KL^{-1}(1 + \frac{1}{T_1 s} + \frac{T_2 s}{1 + aT_2 s})$$

$$\boxed{G_{CL}(s) = \frac{KL^{-1}(1 + \frac{1}{T_1 s} + \frac{T_2 s}{1 + aT_2 s})\frac{AR}{A(sAR+1)}}{1 + KL^{-1}(1 + \frac{1}{T_1 s} + \frac{T_2 s}{1 + aT_2 s})\frac{AR}{A(sAR+1)}}}$$

4. Offset at the output can be found from final value theorem

$$y_{ss} = \lim_{s\to 0} sY(s) = \lim_{s\to 0} sG_{CL}(s)R(s)$$

Assuming step input for simplicity

$$y_{ss} = \lim_{s\to 0} \frac{G_c(s)G(s)}{1 + G_c(s)G(s)}$$

For P-Controller

$$\lim_{s\to 0} G_c(s) = K_p = KL^{-1}$$

$$\lim_{s\to 0} G(s) = \frac{AR}{A} = R$$

$$y_{ss} = \frac{RKL^{-1}}{1 + RKL^{-1}}$$

Thus, the offset can be found as follows;

$$\boxed{offset \;=\; 1 - e_{ss} = 1 - \frac{RKL^{-1}}{1 + RKL^{-1}}}$$

5. For PI-Controller

$$\lim_{s \to 0} G_c(s) \to \infty$$

$$\lim_{s \to 0} G(s) = \frac{AR}{A} = R$$

$$y_{ss} \to 0$$

Thus, the offset can be found as zero.

The pole at the origin due to integral term of the PI controller makes the steady state error zero. The integral term can make system oscillatory or even drive system to unstable region.

6. The noises at the closed loop system can easily be amplified by the derivative component of the controller. To avoid this, alternative variables which can replace the derivative of the processed variable can be used. For example, in a case where the distance is the PV, the controller can use an alternate variable such as **speed** instead of derivative action. Such alternate controllers to PD controllers is called **PV Controllers**.