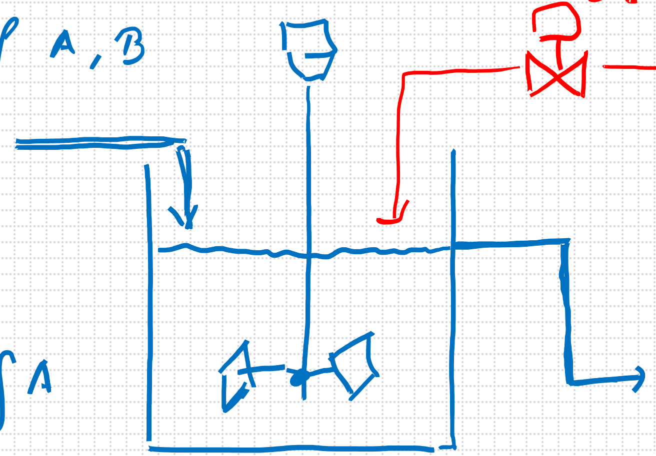
Blending Process Control



OBJECTIVE

Ensure that $x(t)$ remains at the desired value x_{sp}

DESIGN:

1) DIMENSIONING

STEADY-STATE VALUE OF THE MANIPULATED VARIABLE

$$\boxed{\overline{w}_2 = \frac{x_{sp} - \overline{x}_1}{1 - x_{sp}}\,\overline{w}_1}$$

STATIC! $x_1(t)$ VARIES WITH TIME

· ASSUMPTIONS

$w_1(t) = \overline{w}_1$

Volume: constant

Concentr. in the tank $= x(t)$

· BALANCE EQUATIONS

$$\begin{cases} w_1 + w_2(t) = w(t) & (1) \\ w_1 x_1(t) + w_2(t)\cdot 1 = w(t)\, x(t) & (2) \end{cases}$$

$x_2 = 1$

At the steady-state

$x_1(t) = \overline{x}_1 \qquad x(t) = x_{sp}$

$w_1 = \overline{w}_1 \qquad \overline{w}_2$

$x_2 = \overline{x}_2 = 1$

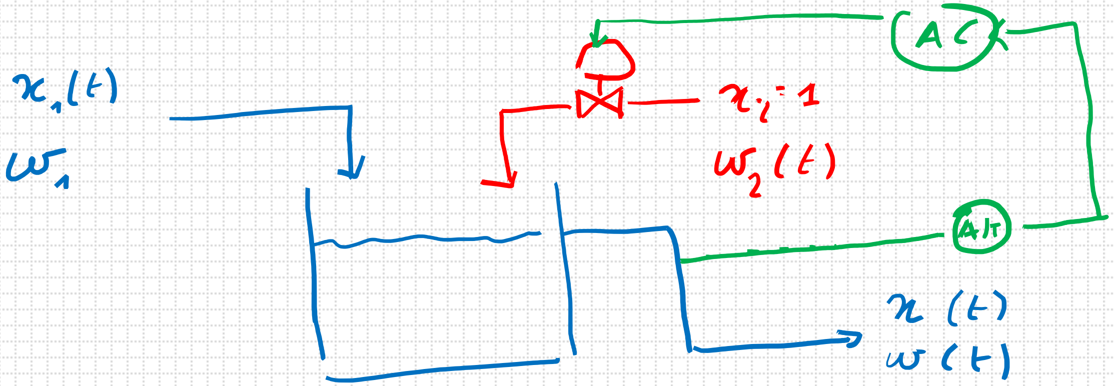
$(1)+(2) \Rightarrow \overline{w}_1\overline{x}_1 + \overline{w}_2 = (\overline{w}_1 + \overline{w}_2)\, x_{sp}$

$$\boxed{\overline{w}_2 = \frac{x_{sp} - \overline{x}_1}{1 - x_{sp}}\,\overline{w}_1} \quad (3)$$

Method 1: FEEDBACK CONTROL

AT: Composition analyzer and transmitter

AC: Actuator / controller



OBJECTIVE: Measure $x(t)$ to vary $w_2(t)$ regardless of $x_1(t)$

$x(t)$: measured variable

$w_2(t)$: manipulated variable

$x_1(t)$: disturbance

· Proportional control law

$$\boxed{w_2(t) - \bar{w}_2 = -K_c\,(x(t) - x_{sp})}$$

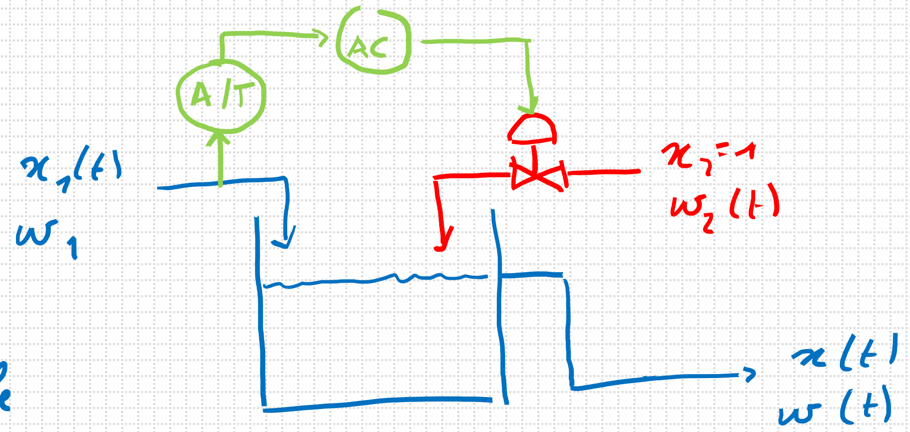
$w_2(t) - \bar{w}_2$: variation of manipulated variable w.r.t. the steady-state value

$x(t) - x_{sp}$: variation of the measured variable w.r.t. the steady-state value

· If the outlet concentration of A decreases (increases) the flow of pure A must increase (decreases)

· Large variations of $x(t)$ from x_{sp} produce large variations of the control action $\Delta w_2(t)$

Feedforward control (Method 2)



OBJECTIVE

Measure $x_1(t)$ to vary $w_2(t)$

↑ disturbance ↑ manipulated variable

Balance equation

$$
\begin{cases}
\bar{w}_2 = \dfrac{x_{sp} - \bar{x}_1}{1 - x_{sp}} \bar{w}_1 & (3) \\[2ex]
w_2(t) = \dfrac{x_{sp} - x_1(t)}{1 - x_{sp}} \bar{w}_1 & (4)
\end{cases}
$$

$w_1(t) = \bar{w}_1$ by assumption

$$(4)-(3): \quad w_2(t) - \bar{w}_2 = \bar{w}_1 \frac{x_{sp} - x_1(t)}{1 - x_{sp}} - \bar{w}_1 \frac{x_{sp} - \bar{x}_1}{1 - x_{sp}} = -\bar{w}_1 \frac{x_1(t) - \bar{x}_1}{1 - x_{sp}}$$

Control law
$$\boxed{\Delta w_2(t) = -\bar{w}_1 \frac{1}{1 - x_{sp}} \Delta x_1(t) = -K_{ff} \Delta x_1(t)}$$

$\Delta w_2(t) := w_2(t) - \bar{w}_2$

$\Delta x_1(t) := x_1(t) - \bar{x}_1$

- If the inlet concentration $x_1(t)$ increases (decreases), the outlet concentration $x(t)$ increases (decreases), the flow of pure A is decreased (increased)

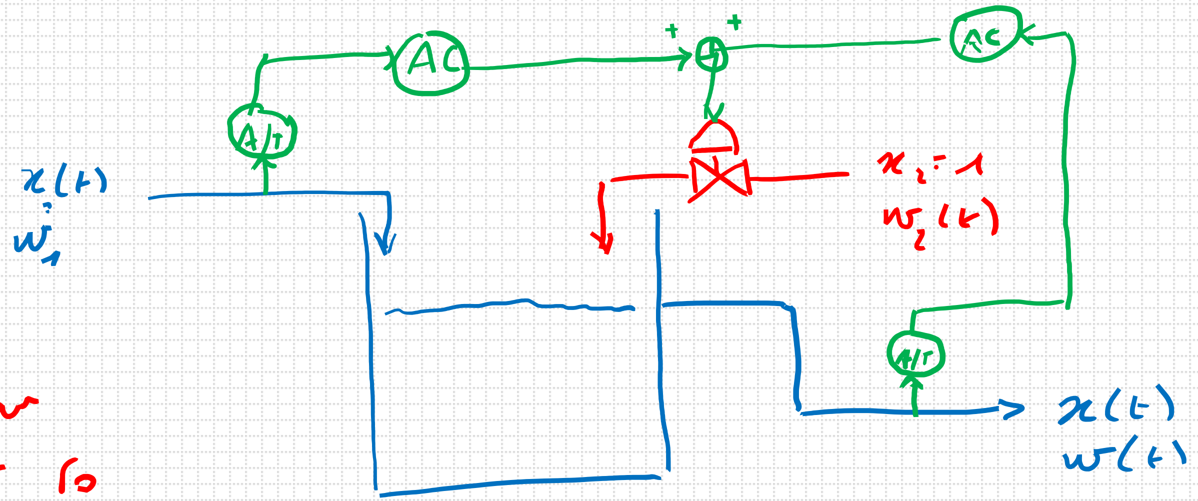
⚠ THE SYSTEM HAS TO START FROM THE STEADY-STATE CONDITIONS

Method 3: feedback + feedforward control (linear systems)

$$\Delta w_2(t) = \underbrace{-K_c \, \Delta x(t)}_{\text{feedback control law}} \underbrace{- K_{ff} \, \Delta x_1(t)}_{\text{feedforward control law}}$$

OBJ: $x(t) \to x_{sp}$

OBJ. react to the disturbance



Method 4: use a larger tank to render the variations of $x_1(t)$ "small"