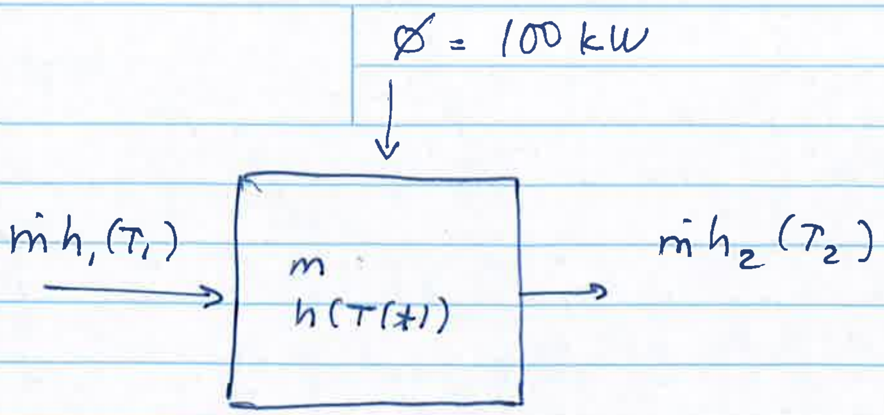


Mass balance $\dot{m}_{in} = \dot{m}_{out} = \dot{m}$

Energy balance

$$\dot{m} h_1(T_1) - \dot{m} h_2(T_2) + \phi = \frac{d(mh)}{dt} = m\frac{dh}{dt}$$

Enthalpy $h = h_0 + \int_{T_0}^{T} c_p \, dT = h_0 + \Big| c_p T \Big|_{T_0}^{T}$

$= h_0 + c_p(T - T_0)$

No reaction, phase change we may drop h_0, assume $T_0 = 0°C$ $\Rightarrow$ $h = c_p T$

$$\dot{m} c_p T_1 - \dot{m} c_p T_2 + \phi = m c_p \frac{dT}{dt}$$

CSTR $\rightarrow$ $T_2 = T$

$$\dot{m} c_p T_1 - \dot{m} c_p T + \phi = m c_p \frac{dT}{dt}$$

1. Steady state $\frac{d}{dt}() = 0$

a) $\phi = 100$ kW fixed, T = free

$\dot{m} c_p T_1 - \dot{m} c_p T + \phi = 0$ $\quad T = \frac{\dot{m} c_p T_1 + \phi}{\dot{m} c_p}$

$$= T_1 + \frac{\phi}{\dot{m} c_p} = 25°C + \frac{100\,000 \text{ W}}{1 \cdot 4200} = 48.8\,°C$$

1b $T_2 = T = 100°C$, ϕ = free

$$\phi = \dot{m} c_p (T - T_0) = 1 \cdot 4200 (100 - 75)$$
$$= 315 \text{ kW}$$

You need to think what are fixed and free, left to be solved. If all is fixed, problem is overdefined
→ no solution in steady state.

2. Transient case $\frac{dT}{dt} \neq 0$ $t = 0$

$$\underbrace{\dot{m} c_p T_1 + \phi}_{a} - \underbrace{\dot{m} c_p}_{b} T = \underbrace{m c_p}_{d} \frac{dT}{dt}$$

$T(t) = ?$
$t = 0$ $T_0 = 100°C$
$\phi = 100 \text{ kW}$

$$a - bT = d \frac{dT}{dt}$$

$$\int_{T_0}^{T(t)} \frac{dT}{a - bT} = \int_0^t \frac{dt}{d} \iff -\frac{1}{b} \ln\left(\frac{a - bT}{a - bT_0}\right) = \frac{t}{d}$$

$$\frac{a - bT}{a - bT_0} = \exp\left(-\frac{b}{d} \cdot t\right) = \exp\left(-\frac{t}{\tau}\right) \qquad \frac{b}{d} = \frac{\dot{m} c_p}{m c_p} = \frac{\dot{m}}{m} = \frac{1}{\tau}$$

τ = residence time

$$a - b \cdot T = (a - bT_0) \cdot \exp\left(-\frac{t}{\tau}\right)$$

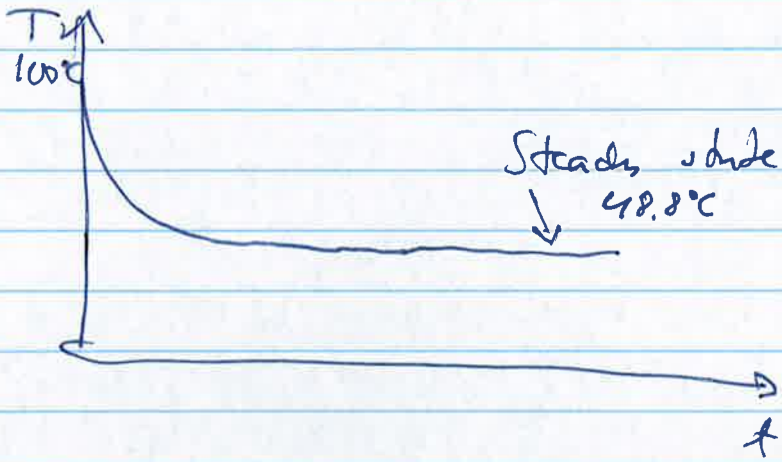
$$T = \frac{a}{b} - \left(\frac{a}{b} - T_0\right) \exp\left(-\frac{t}{\tau}\right)$$

$$T(t) = \frac{\dot{m} c_p T_1 + \phi}{\dot{m} c_p} - \left(\frac{\dot{m} c_p T_1 + \phi}{\dot{m} c_p} - T_0 \right) \cdot \exp\left(-\frac{t}{\tau}\right)$$

$$T(t) = T_1 + \frac{\phi}{\dot{m} c_p} - \left(T_1 - T_0 + \frac{\phi}{\dot{m} c_p} \right) \exp\left(-\frac{t}{\tau}\right)$$

$$= \left(T_1 + \frac{\phi}{\dot{m} c_p} \right) \left(1 - \exp\left(-\frac{t}{\tau}\right) \right) + T_0 \exp\left(-\frac{t}{\tau}\right)$$

To Excel →



This case was probably trivial, but often students overdefine first cases. :)