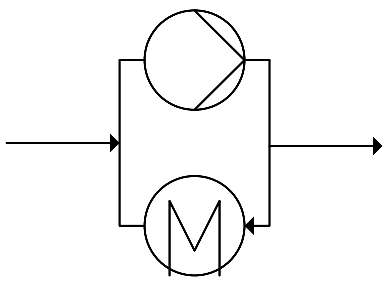
Exercise 9

An exothermic reaction is currently carried out in a batch reactor.

You are asked to evaluate the feasibility of running the process continuously in a loop reactor equipped with an inline heat exchanger.



Reaction data

$r = kc_A (mol \cdot m^{-3} \cdot s^{-1})$ $k_0 = 10^6 \, s^{-1}$ $E_a = 35 \, kJ \cdot mol^{-1}$ $\Delta H_r = -150 \, kJ \cdot mol^{-1}$

Molecular weight of reactant A: $MW = 0.13 \, kg \, mol^{-1}$

Density of A: $\rho = 900 \, kg \, m^{-3}$

Heat capacity of A: $c_p = 2200 \, J \, kg^{-1} \, K^{-1}$

Batch process data

Reactor volume: 6.3 m^3

Solvent used: 3500 kg

Reactant A added: 300 kg

Addition time of A: 5 h

Batch cycle time: 20 h

Temperature of A: 20°C

Cooling temperature: -20°C

Reaction temperature: 0°C

Loop reactor data

Inlet flow temperature=20°C

$UA = 1000 \, W \cdot K^{-1}$

Questions

- What is the required loop-reactor volume and cooling fluid temperature to maintain the same conversion (99%) and productivity as the batch process in the absence of solvent at a reaction temperature of 0°C? What is the intensification factor?
- What would be the reactor volume and reaction temperature in the absence of solvent assuming that a cooling fluid at 20°C has to be used?
- What are the benefits of a change from batch-to-continuous for this latter case?

Assumptions: Inlet temperature of A=20°C, constant c_p, kinetic constants remain valid without solvent, heat transfer coefficient independent of concentration, loop reactor behaves as an ideal CSTR.

Subsidiary question

Repeat the exercise by treating the reactor as a tubular recycle reactor, with the following loop recirculation flowrate.

$$\text{Loop recirculation pump flowrate} = 1000\ \text{kg/h}$$