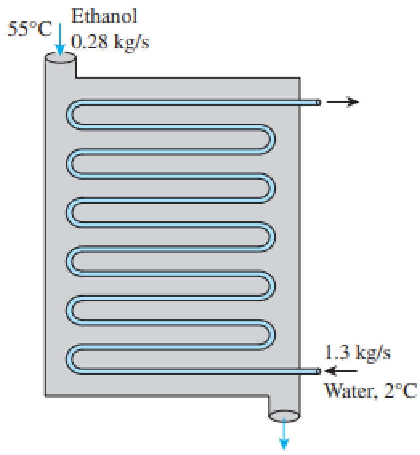
Problem Statement-4

PART-A

- Ethanol is classified by the National Fire Protection Association (NFPA) as a flammable fluid because of its low flash point of 178C. This means that at 178C or higher, ethanol can vaporize and become a mixture in air that would ignite when an ignition source is present. Thus, in an environment that ignition sources are present, keeping ethanol at a temperature below its flash point can help to prevent fire hazard.
- Consider a process where ethanol is cooled by water in a 1-shell-pass heat exchanger that can accommodate a maximum of 14-tube-passes. The tubes are made of copper and thin-walled with an inner diameter of 1.5 cm.
- The length of each tube pass that can be fitted inside the heat exchanger is 3 m, and the overall heat transfer coefficient is 700 W/m2·K. Ethanol (cp 5 2630 J/kg·K) enters the heat exchanger at 55°C and flows through the shell at a rate of 0.28 kg/s. Water enters the heat exchanger at 28C and flows through the tubes at a rate of 1.3 kg/s. To prevent fire hazard, the ethanol is to be cooled to 15°C, which is below its flash point.
- **Determine the number of tube passes that is necessary inside the shell-and tube heat exchanger to cool the ethanol to the prescribed temperature.** Discuss whether or not this heat exchanger is suitable for this application. Evaluate any required property of water at 58C. Is this a good assumption?
- Vary the outlet hot fluid temperature ($T_{h,out}$) and **plot number of tube passes 'n' vs outlet hot fluid temperature ($T_{h,out}$)**.



PART-B

- Now, keeping all the inlet conditions ($T_{c,in}$ and $T_{h,in}$) to be same, vary the number of tube passes (n) from 1 to 14 and find out the effectiveness and outlet coolant and outlet hot fluid temperatures ($T_{c,out}$ and $T_{h,out}$).
- **Plot outlet coolant temperature ($T_{c,out}$) vs number of tube passes 'n'. Determine the point of infeasibility**.

PART-C

- Suppose instead of shell and tube heat exchanger, you have a different heat exchanger like:
    a) Double-pipe: Parallel-flow
    b) Double-pipe: Counter-flow
    c) Cross-flow (single pass): C_{max} mixed, C_{min} unmixed
    d) Cross-flow (single pass): C_{min} mixed, C_{max} unmixed
- Keeping all the conditions same as PART-A, determine the effectiveness of each of the above mentioned heat exchangers.
- Now, out of all the heat exchangers (shell and tube , and the 4 mentioned here), which heat exchanger gives the highest effectiveness. Can you predict the reason behind this trend?

PART-D

- Write down the applications of double-pipe (parallel and counter), shell & tube and Cross-flow heat exchangers.
- Mention the cases where each of them are useful. Moreover, which heat exchanger do you think is used in our daily life.

TABLE 11–4

Effectiveness relations for heat exchangers: NTU $= UA_s/C_{min}$ and $c = C_{min}/C_{max} = (\dot{m}c_p)_{min}/(\dot{m}c_p)_{max}$

Heat exchanger type	Effectiveness relation
1 *Double pipe:*	
Parallel-flow	$\varepsilon = \dfrac{1 - \exp[-\text{NTU}(1+c)]}{1+c}$
Counter-flow	$\varepsilon = \dfrac{1 - \exp[-\text{NTU}(1-c)]}{1 - c\exp[-\text{NTU}(1-c)]}$ (for $c < 1$)
	$\varepsilon = \dfrac{\text{NTU}}{1+\text{NTU}}$ (for $c = 1$)
2 *Shell-and-tube:* One-shell pass 2, 4,…tube passes	$\varepsilon_1 = 2\left\{1 + c + \sqrt{1+c^2}\,\dfrac{1+\exp\left[-\text{NTU}_1\sqrt{1+c^2}\right]}{1-\exp\left[-\text{NTU}_1\sqrt{1+c^2}\right]}\right\}^{-1}$
n-shell passes 2*n*, 4*n*, … tube passes	$\varepsilon_n = \left[\left(\dfrac{1-\varepsilon_1 c}{1-\varepsilon_1}\right)^n - 1\right]\left[\left(\dfrac{1-\varepsilon_1 c}{1-\varepsilon_1}\right)^n - c\right]^{-1}$
3 *Cross-flow (single-pass)* Both fluids unmixed	$\varepsilon = 1 - \exp\left\{\dfrac{\text{NTU}^{0.22}}{c}\left[\exp(-c\,\text{NTU}^{0.78}) - 1\right]\right\}$
C_{max} mixed, C_{min} unmixed	$\varepsilon = \dfrac{1}{c}(1 - \exp\{-c[1 - \exp(-\text{NTU})]\})$
C_{min} mixed, C_{max} unmixed	$\varepsilon = 1 - \exp\left\{-\dfrac{1}{c}[1 - \exp(-c\,\text{NTU})]\right\}$
4 *All heat exchangers with* $c = 0$	$\varepsilon = 1 - \exp(-\text{NTU})$

TABLE 11–5

NTU relations for heat exchangers: $\text{NTU} = UA_s/C_{min}$ and $c = C_{min}/C_{max} = (\dot{m}c_p)_{min}/(\dot{m}c_p)_{max}$

Heat exchanger type	NTU relation
1 *Double-pipe:*	
Parallel-flow	$\text{NTU} = -\dfrac{\ln[1 - \varepsilon(1 + c)]}{1 + c}$
Counter-flow	$\text{NTU} = \dfrac{1}{c - 1}\ln\left(\dfrac{\varepsilon - 1}{\varepsilon c - 1}\right)$ (for $c < 1$)
	$\text{NTU} = \dfrac{\varepsilon}{1 - \varepsilon}$ (for $c = 1$)
2 *Shell and tube:* One-shell pass 2, 4,…tube passes	$\text{NTU}_1 = -\dfrac{1}{\sqrt{1 + c^2}}\ln\left(\dfrac{2/\varepsilon_1 - 1 - c - \sqrt{1 + c^2}}{2/\varepsilon_1 - 1 - c + \sqrt{1 + c^2}}\right)$
n-shell passes 2*n*, 4*n*,…tube passes	$\text{NTU}_n = n(\text{NTU})_1$ To find effectiveness of the heat exchanger with one-shell pass use, $\varepsilon_1 = \dfrac{F - 1}{F - c}$ where $F = \left(\dfrac{\varepsilon_n c - 1}{\varepsilon_n - 1}\right)^{1/n}$
3 *Cross-flow (single-pass):* C_{max} mixed, C_{min} unmixed	$\text{NTU} = -\ln\left[1 + \dfrac{\ln(1 - \varepsilon c)}{c}\right]$
C_{min} mixed, C_{max} unmixed	$\text{NTU} = -\dfrac{\ln[c\ln(1 - \varepsilon) + 1]}{c}$
4 *All heat exchangers with* $c = 0$	$\text{NTU} = -\ln(1 - \varepsilon)$

- Create a zip file consisting of your code file (.m file) & the report and submit it to 190588.simutech@gmail.com & chemineers01@gmail.com.
- Deadline: Submission due by 23:59 P.M., Monday, 9th May, 2022.