Abd-elhafid Boussouf University – Mila
Faculty of Science & Technology
Process Engineering – Ch.E
Unit Operations II – UEF 1.2.1

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In-Class Exercises n°03

Exercise 3.1 – Single-Effect Evaporator Design

A solution is concentrated in a single-effect evaporator from **8 wt%** to **32 wt%** solids. The feed flowrate is **4000 kg/h**, entering at **25°C**. The boiling temperature is **95°C**.

Data: C_p = 4.18 kJ/kg; λ = 2300 kJ/kg; U = 1400 W/m^2·K; ΔT = 30°C

Determine:

- Determine the required heat transfer area **A**;

If fouling reduces U to **800 W/m²·K**:

- Recalculate the required area
- Comment on the impact

Exercise 3.2 – Industrial Evaporation of NaOH

A chemical plant concentrates an aqueous NaOH solution using **a single-effect evaporator**. The feed contains **12 wt%** NaOH and must be concentrated to **48 wt%**.

Operating conditions:

- Feed flowrate: **F = 10,000 kg/h**
- Feed temperature: **T_{in} = 40°C**
- Nominal boiling temperature: **105°C**
- Boiling point elevation (BPE): **10°C**

Thermophysical data: C_p = 3.6 kJ/kg; λ = 2200 kJ/kg

Heat transfer data:

- Steam temperature: **135°C**
- Overall heat transfer coefficient: **U = 1100 W/m^2·K**

1. Calculate the total heat required Q (kJ/h), including: sensible heat and latent heat;

2. Determine the effective temperature difference ΔT;

3. Calculate the required heat transfer area A;

4. What is the impact of boiling point elevation (BPE) on evaporator design?

5. Why is NaOH evaporation more difficult than water evaporation?

Exercise 3.3 – Double-Effect Evaporator

A **5.0 wt%** sugar solution at **110°C** and **2.0 bar** is fed to a double-effect evaporator.

The first effect operates at **1.0 bar** pressure and concentrates the sugar to **8.0 wt%**. It is heated by saturated steam at **140°C**; the condensate leaves **evaporator 1** as saturated liquid.

The second effect operates at **0.12 bar** pressure. The overall heat transfer coefficient is **2.0 kJ/(m².s.K)** for the first effect and **1.6 kJ/(m².s.K)** for the second effect. The heat transfer area is **56 m²** in each effect.

The results of mass and energy balances on the first evaporator: the feed rate of **5.0 wt%** sugar solution is **5.61 kg/s**, the steam feed rate is **2.10 kg/s**, the rate that water is evaporated is **2.11 kg/s**, and the **8.0 wt%** stream flow rate is **3.51 kg/s**.

- What is the sugar concentration leaving the second effect?
- What is the steam economy for the system (kg water evaporated per kg of steam condensed)?