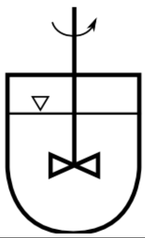
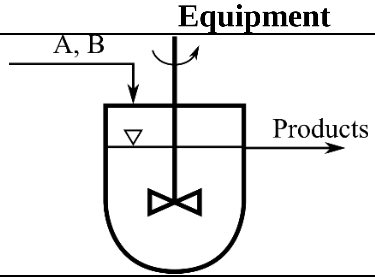
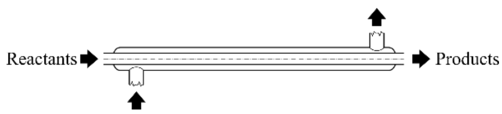
1. seminar: calculation of batch ractors: isotherm and adiabatic cases

R1. Problem

An A+B→C+D type reaction is performed in an isotherm, mixed, batch tank reactor at 80 °C. The initial concentrations of both A and B components are 5.2 mol/dm^3 . The volume of the reaction mixture is constant during the whole reaction. How long does it take to reach 85% conversion? The reaction can be described with second order kinetics, thus $r = k \cdot c_A \cdot c_B$, where $k = 0.058 \frac{m^3}{kmol \cdot min}$

Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment		
		

Mode of operation	
Isothermal	Adiabatic

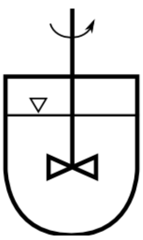
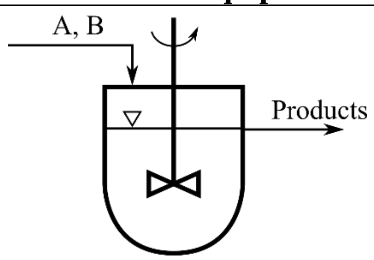
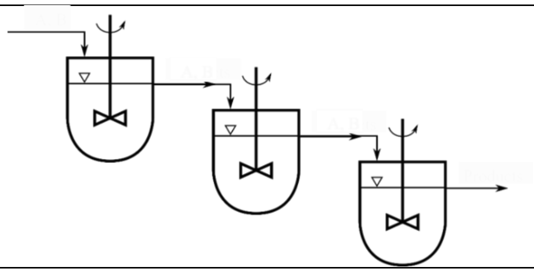
R2. Problem

A perfectly mixed adiabatic bath reactor, with 2.5 m^3 inner volume, is installed for an A→B type irreversible liquid phase reaction. The initial reaction mixture is at 25 °C, it contains 11.25 kmol A component, and no B component. The enthalpy of reaction is -20 MJ/kmol, the specific heat capacity of the mixture is 2200 J/(kg·K), density is 850 kg/m^3 . The reaction is stopped at 70 °C. The reaction rate coefficient can be calculated by the following equation: $k = 10^{13} \cdot e^{-\frac{12000}{T}} s^{-1}$.

Calculate the conversion! Homework: calculate the reaction time!

Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment		
		

Mode of operation	
Isothermal	Adiabatic

2. seminar: isothermal and adiabatic plug flow reactors

<u>R3. problem</u>

A pseudo-first order reaction is performed in an ideal plug flow rector of 3 m^3 inner volume. The reaction rate coefficient is 0.0806 min^{-1}. Calculate the conversion if the flow rate of the feed is 0.1 m^3/min or is it is 0.15 m^3/min!

Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

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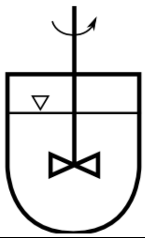
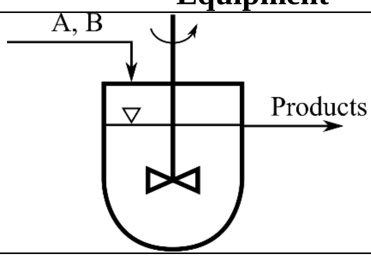
<td></td>
<td>
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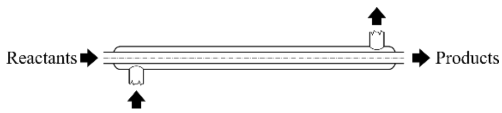
<td>
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Mode of operation	
Isothermal	Adiabatic

R4. problem

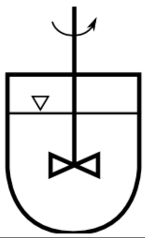
An adiabatic plug flow reactor is used for a second order reaction. The flow rate of the feed A at 20 °C is 10 dm^3/s, containing 7.5 mol/dm^3 A. The flow rate of the feed B at 20 °C is 20 dm^3/s, containing 3.75 mol/dm^3 B. The type of reaction is: A+B→2R. Conversion should be 95%. The enthalpy of reaction is -82 kJ/mol, density of the mixture is 1050 kg/m^3 , specific heat capacity is 3.5 kJ/(kg·K). The reaction rate coefficient can be calculated by the following equation: $k = 1.63 \cdot 10^{10} \cdot e^{-\frac{8100}{T}} \frac{dm^3}{mol \cdot s}$

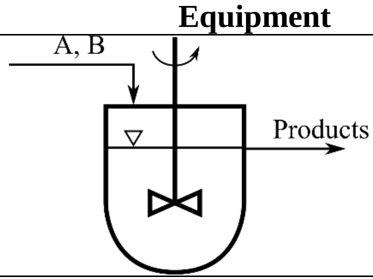
Calculate the necessary reactor volume!

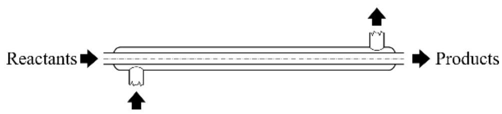
Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment







Mode of operation	
Isothermal	Adiabatic

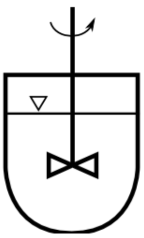
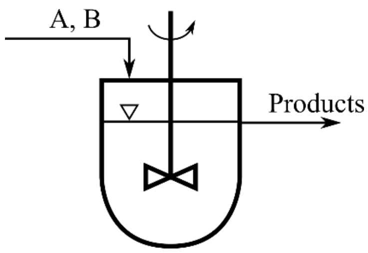
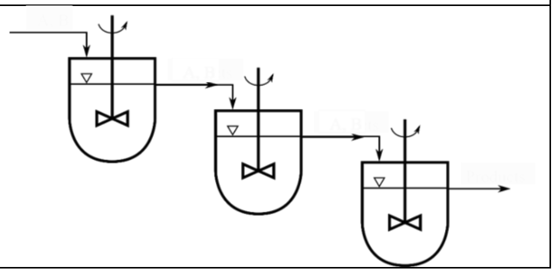
3. seminar: CSTR (isothermal and adiabatic), consultation

R5. Problem

An A+B $\underset{k_{-1}}{\overset{k_1}{\longleftrightarrow}}$ C+D type equilibrium reaction is performed in a continuously stirred tank reactor of 0.12 m^3 inner volume. The conversion should be 75%. The feed flow rates are equal and contain only one of the substrates. The concentration of feed A is 2.8 mol/dm^3, the concentration of feed B is 1.6 mol/dm^3. k_1 = 7 dm^3/mol·min, k_{-1} = 3 dm^3 /mol·min at 60 °C. k_1 = 6.3 dm^3/mol·min, and k_{-1} = 2.8 dm^3/mol·min at 40 °C. Calculate the maximal flow rate in order to achieve the required conversion at 60 °C and at 80 °C (homework).

Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment		
		

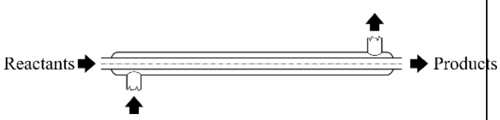
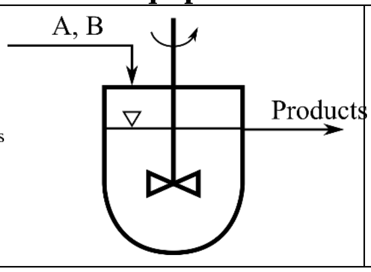
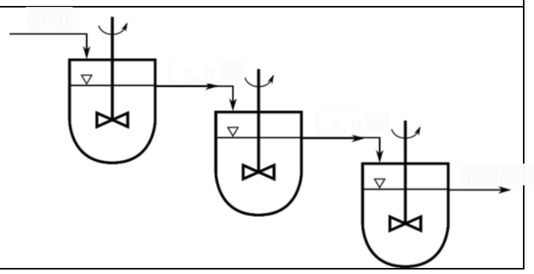
Mode of operation	
Isothermal	Adiabatic

R6. Problem

An adiabatic, continuously stirred tank reactor is used for a second order reaction. The flow rate of the feed A at 20 °C is 10 dm^3/s, containing 7.5 mol/dm^3 A. The flow rate of the feed B at 20 °C is 20 dm^3/s, containing 3.75 mol/dm^3 B. The type of reaction is: $A+B \rightarrow 2R$. Conversion should be 95%. The enthaply of reaction is -82 kJ/mol, density of the mixture is 1050 kg/m3 , specific heat capacity is 3.5 kJ/(kg·K). The reaction rate coefficient can be calculated by the following equation: $k = 1.63 \cdot 10^{10} \cdot e^{-\frac{8100}{T}} \frac{dm^3}{mol \cdot s}$ Calculate the necessary reactor volume! Compare your result with the result of the R4 problem. Consulation.

Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment		
		

Mode of operation	
Isothermal	Adiabatic

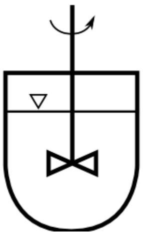
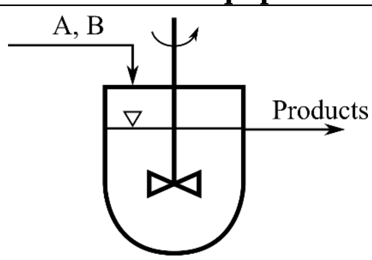
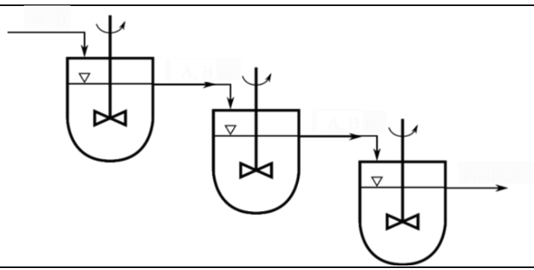
R7. Problem

A liquid phase $A + B \rightarrow C + D$ reaction is performed under isotherm conditions. Two ideal tubular reactors are available with a volume of 0.5 m^3 each. The flowrate of the feeding streams is 25 kmol/h each, while the concentration of the reagents is 20 $kmol/m^3$. The reaction can be considered second order. At inlet temperature, 25 °C, the value of the reaction rate coefficient is 0.125 $m^3/(kmol \cdot h)$.

a) Calculate conversion in the reactors separately and summarized if the reactors are connected consecutively. Calculate the quantity of component C leaving the reactors.
b) What conversion can be reached by connecting the reactors parallelly and dividing the feed streams equally between them?

c) Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment		
		

Mode of operation	
Isothermal	Adiabatic

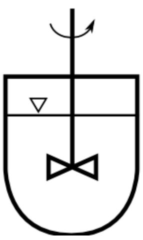
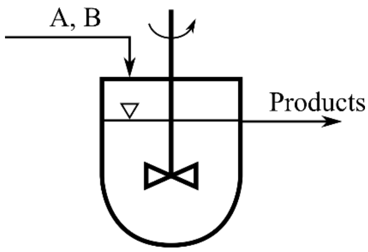
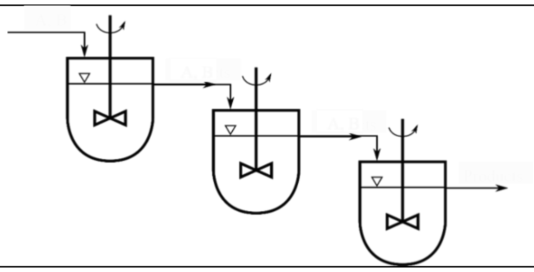
R8 problem

An $A + B \rightarrow C + D$ type, second order, irreversible reaction is conducted in a three element cascade consisting of vessels with a useful volume of 2 m^3 each. The first reactor is fed with 333 kg/h of A and 111 kg/h of B. Besides the stream arriving from the first reactor, 148 kg/h B is also filled into the second vessel. The molar masses of the components: M_A=222 g/mol, M_B=74 g/mol, M_C=278 g/mol, M_D= 18 g/mol. Upon entering the reactor, the feed streams mix immediately and completely and all of the reactor vessels can be considered perfectly mixed tank reactors. The density of the reaction mixture is 1058 kg/m^3, remaining constant during the reaction. Every element of the cascade is operating under isotherm conditions, at 40 °C. The reaction rate coefficient is $1.25 \cdot 10^{-3}$ m^3/(kmol·min).

a) Determine the mass of product C forming in an hour.
b) How many kg of product can be formed if one single 2 m^3 reactor is applied instead of the cascade? Feeding streams remain the same: 333 kg/h of A and 111 kg/h of B.

d) Data given in the example (including reaction order and reversibility)			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment		
		

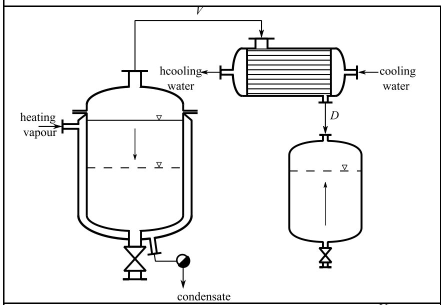
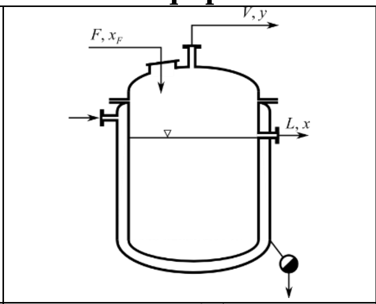
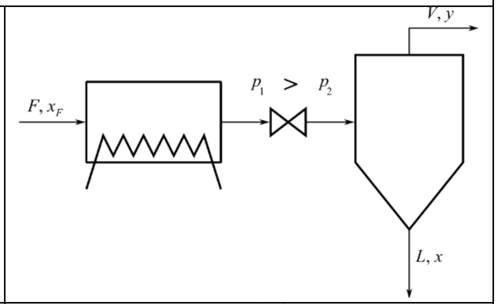
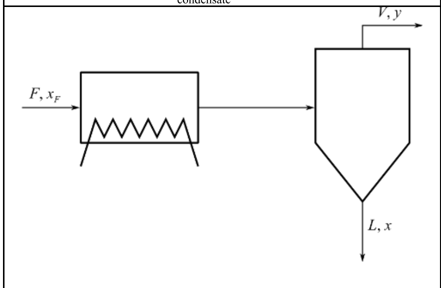
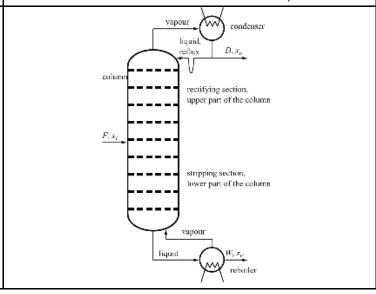
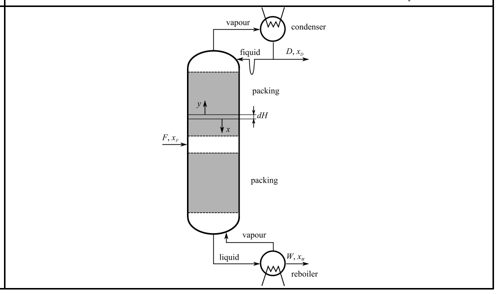
Mode of operation	
Isothermal	Adiabatic

D1. Problem

10 kmol ethanol – water mixture, with 20 mol% ethanol content, is purified until 2 mol% ethanol content in the residue by batch distillation. Calculate the molar amount and mass of the distillate and of the residue. Calculate the composition of the distillate.

Data given in the example			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment		
		
		

D2. Problem

An ethanol – water mixture (100 kmol/h flow rate, 0.3 molar fraction) is distilled by flash distillation at 86 °C. Calculate the molar flowrate and the composition of the distillate and of the residue. Determine the operational limits of the separation.

Data given in the example			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

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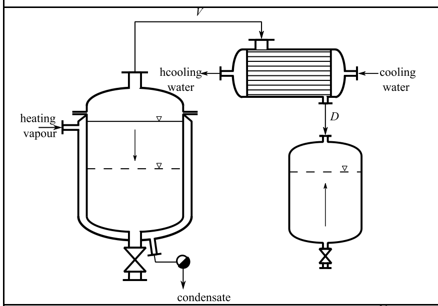

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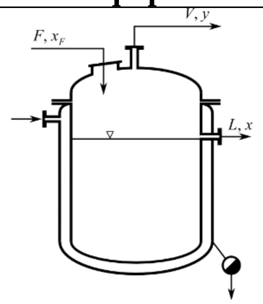

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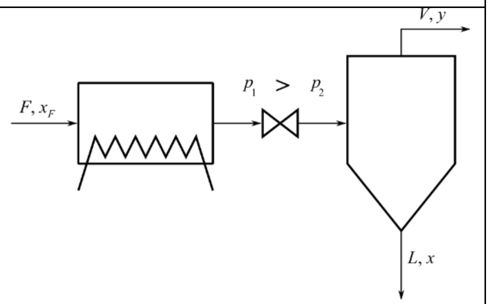

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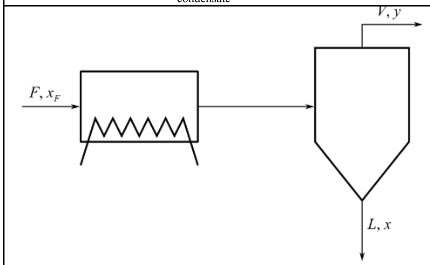

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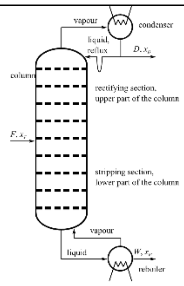

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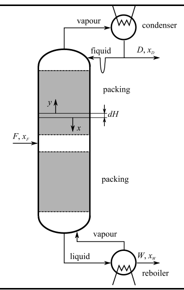

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D3. Problem

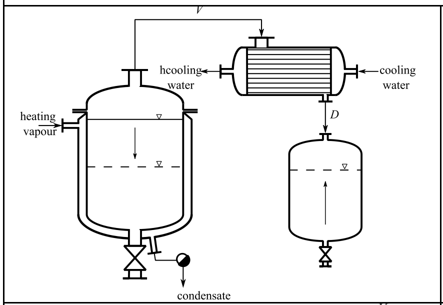
A propanol-isopropanol mixture having an isopropanol content of 45 mass percent with a mass flowrate of 2104 kg/h is separated on a continuously operating distillation column at ambient pressure. The products contain 90 mass percent of isopropanol and 95 mass percent of propanol respectively. The feed is a boiling liquid and its position is optimal. The mixture of propanol and isopropanol can be considered ideal.

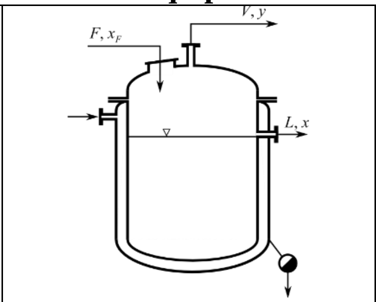
a) How much is molar flowrate of the distillate and the residue?
b) Determine the minimal number of plates.
c) Determine the minimal reflux ratio.

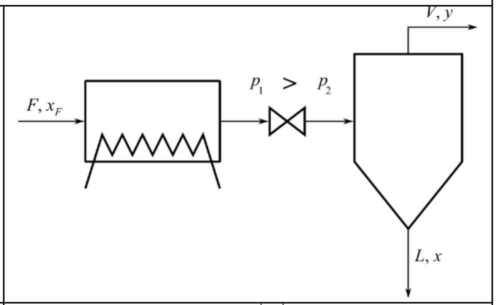
d) Data given in the example			
Name	**Notation**	**Numerical quantity**	**Unit**

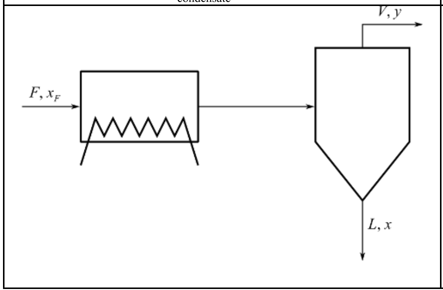
Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

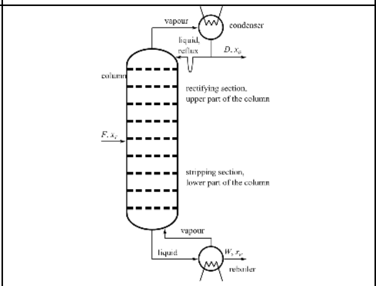
Equipment

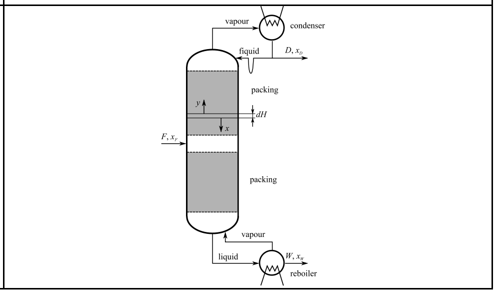












D4. Problem

At atmospheric pressure 1.2 kmol/h phenol and metacresol mixture (55 mol% phenol content) is distilled in a packed distillation column. According to the measurements if the reflux ratio is 6, the metacresol contamination int he phenol stream is 10 mol%, while the phenol content of the metacresol stream is 6 mol%. The column is installed with a partial reboiler. The feed is 20% vapour, 80% liquid, its position is optimal.

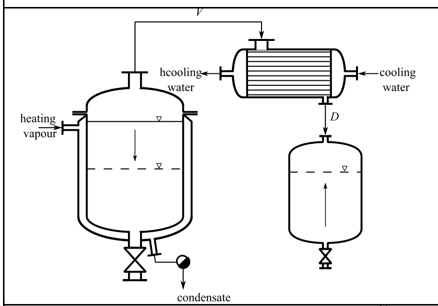
a) Determine the HETP value if the height of the packing is 3.2 m!

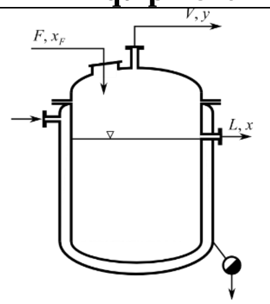
b) Diameter of the column is 25 cm. Calculate the load factor at the bottom of the column! Pressure drop of the column is negligible.

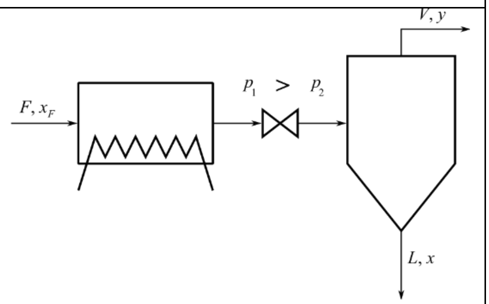
c) Data given in the example			
Name	**Notation**	**Numerical quantity**	**Unit**

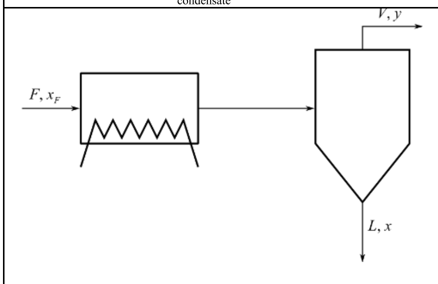
Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

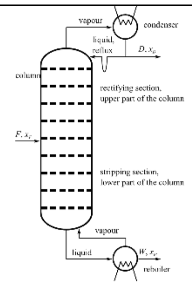
Equipment

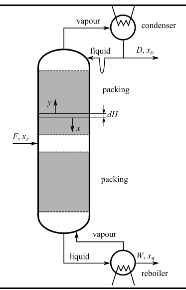












D5. Problem

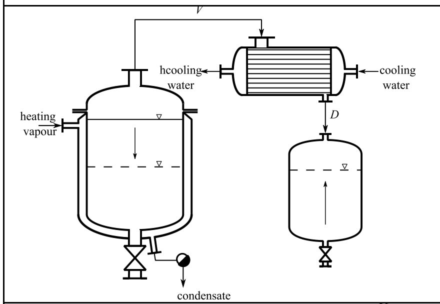
8500 kg/h 50 mol% benzene-toluene mixture is separated in a continuous distillation column. Molar fraction of benzene in the distillate is 0.95 while that in the residue is 0.05.Reflux ratio is R=3. Enthalpy of evaporation: 30336 kJ/kmol, specific heat capacity: 1,844 kJ/kgK.

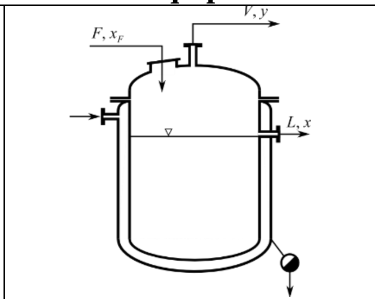
a) Give the mass flow rates of the distillate and of the residue.
b) Give the minimal number of theoretical plates to achieve the certain separation if the feed is liquid, 20 °C.
c) Calculate the number of real plates if the average plate efficiency is 75%. d) Give the diameter of the column, if the average efficiency of plates is 75%, pressure drop is 4 torr/plate and F-factor is 1.4 $Pa^{1/2}$?
d) Give the amount of heating water vapour (3 bar) and cooling water consumption, if the inlet temperature of water is 20 °C and temperature increase have to be below 20 °C.

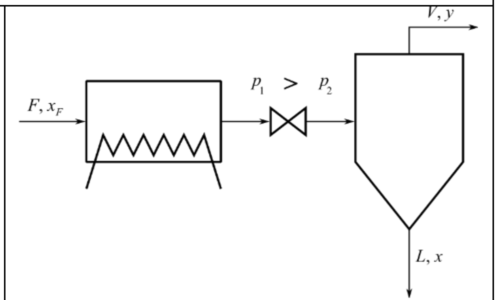
Data given in the example			
Name	**Notation**	**Numerical quantity**	**Unit**

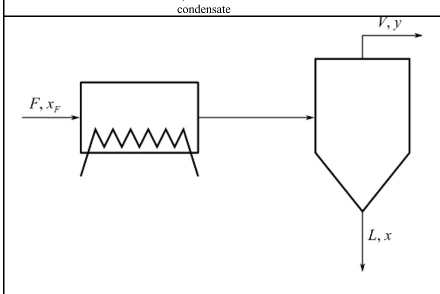
Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

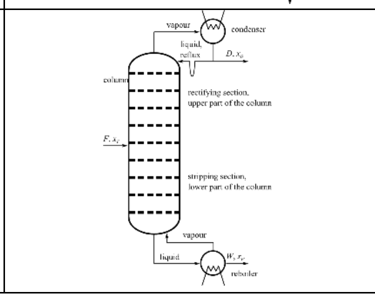
Equipment

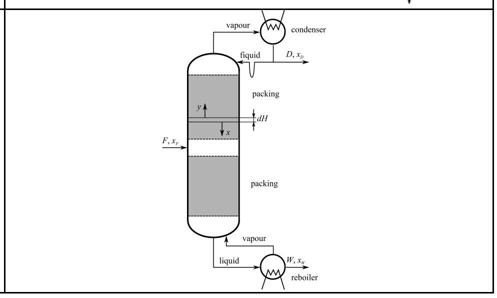












D6. Problem

In a packed column a phenol-metacresol mixture is separated to a phenol stream of 90 mol% phenol and to a metacresol stream of 92 mol% metacresol content. The molar flow rate of the feed is 1 kmol/h, its phenol content is 40 mol%. The reflux ratio is 7. The feed is a mixture of vapour and liquid with 80% liquid. Position of inlet is optimal. Based on experimental results, the mass transfer coefficient is 0.59 mol/m^2 s. The diameter of the column is 23.4 cm.

a) Calculate the number of transfer units and the height of the transfer units both in the upper and lower sections of the column! Calculate the height of the column!

b) Calculate the value of the F factor in the bottom and in the top of the column! (homework)

Data given in the example			
Name	**Notation**	**Numerical quantity**	**Unit**

Data to be calculated			
Name	**Notation**	**Numerical quantity**	**Unit**

Equipment