PRRE1003 Resources, Processes & Materials

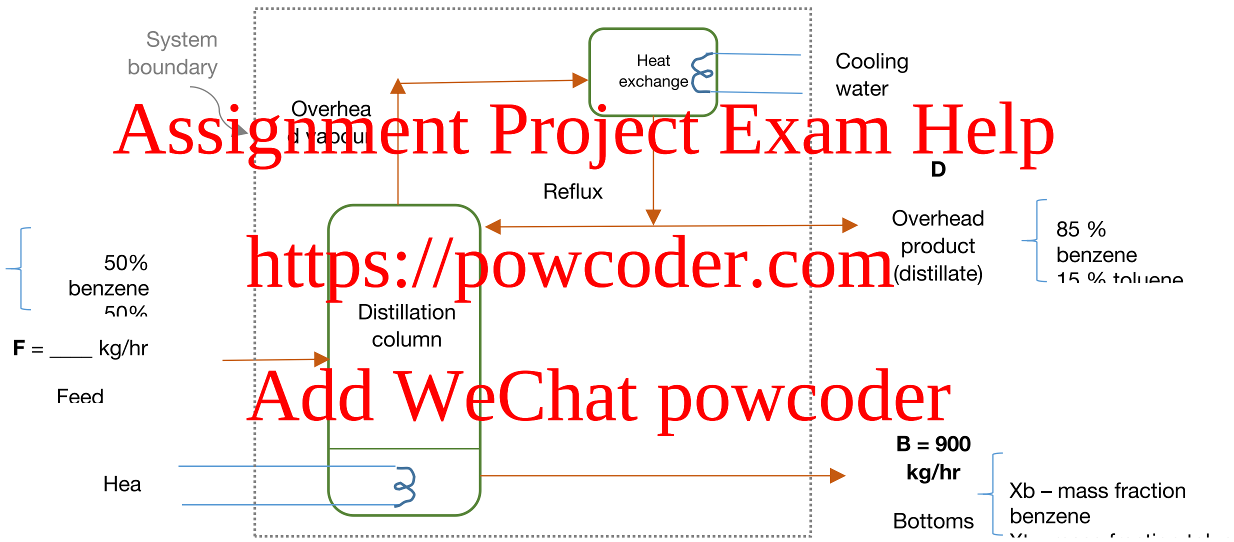
Workshop P4: Hydrocarbon Processing

LEARNING OUTCOMES

- Understand the principle of distillation as a separation process
- Material and energy requirements of a distillation column
- Understand the meaning of heating value of a hydrocarbon
- Understand how different fuels can be used to produce electricity

Activity 1: Material Balance on a Distillation Column (30 minutes)

The following diagram shows a distillation column used to separate a mixture of benzene and toluene. **Perform a material balance** to determine the composition of the bottoms product. Use the first 4 digits of your student ID as the feed in kg/hr.



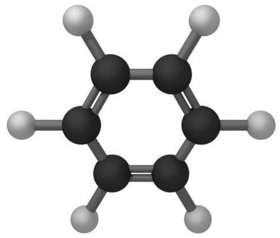
Basis: 1 hour of operation

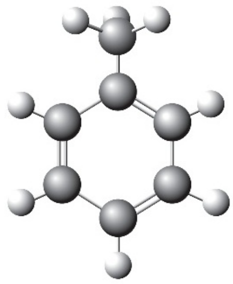
Feed F *(input first 4 digits of your student ID)*	kg
Total material balance (kg)	(equation 1)
Overhead product D (kg)	
Component material balance (kg)	(equation 2)
Sum of mass fractions	(equation 3)
Composition of bottoms product (%)	toluene, benzene
Composition of bottoms product (kg)	toluene, benzene

Activity 2: Energy Requirements for a Distillation Column (20 minutes)

Benzene and toluene are liquids at room temperature. The boiling points of benzene and toluene are 80°C and 111°C respectively, and their structures are given below:

benzene





toluene

(a) Benzene makes up most of the overhead product because it has a lower boiling point. **Explain this in relation to the structures.**

(b) **At which temperature** do you think the top of the distillation column needs to be? Why?

(c) **Why is energy required** for the distillation column? **Why is a heat exchanger needed** for the overhead product?

Activity 3: Heating Value of Hydrocarbons (45 minutes)

The general schematic of a power plant is shown in the Figure below. The fuel is usually a hydrocarbon, and provides energy to heat up the water in the boiler, to make steam, which drives a steam turbine. For simplicity, assume that methane (CH_4) is the fuel, but the analysis below can apply to any hydrocarbon.

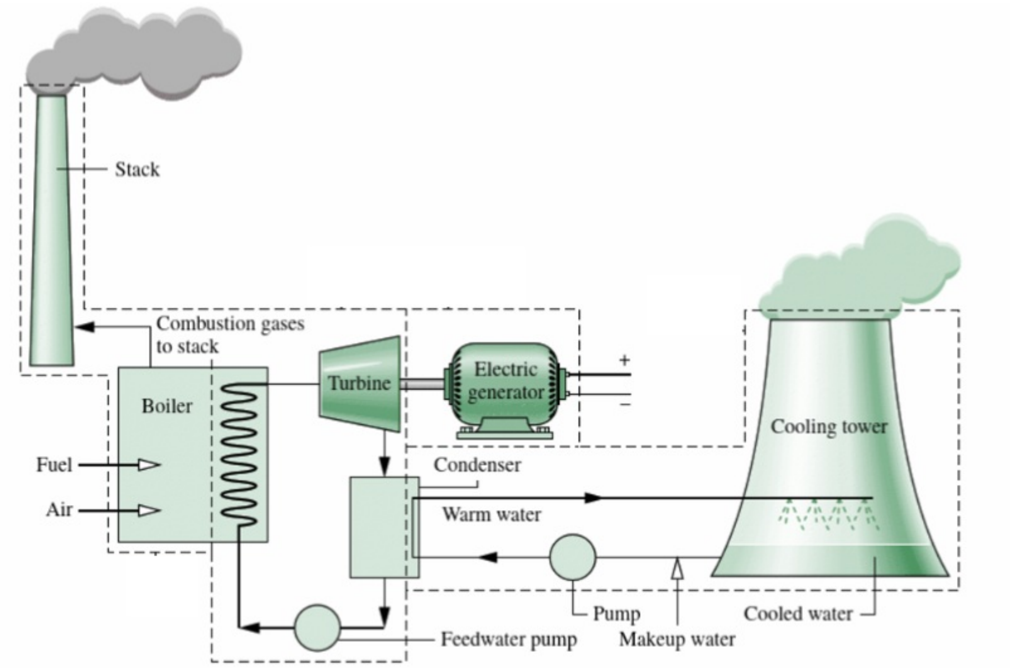


Figure: Adapted from Moran MJ, Shapiro HN . Fundamentals of Engineering Thermodynamics. 5[th] ed. Chichester, West Sussex, England: John Wiley & Sons, 2006. Chapter 8: Vapor Power Systems; p.325-326.

CH_4 can combust completely with the O_2 in air to produce CO_2 and H_2O. However, if combustion is incomplete, CO can be formed instead of CO_2. The efficiency of a heat engine is given by

$$\eta_{cycle} = \frac{electricity\ output}{heat\ input}$$

Complete combustion:	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	(A)
Incomplete combustion:	$CH_4 + \frac{5}{4}O_2 \rightarrow \frac{1}{2}CO + 2H_2O + \frac{1}{2}C$	(B)

When methane reacts with oxygen in air, parts of it may undergo one or both of the reactions above. The heats of reaction are 802 kJ and 464 kJ (per mole of CH_4 burnt) respectively for reactions A and B, if water is in the vapour phase as a product. The heat engine efficiency is 35%.

(a) Using equation A, **discuss in your group why energy is released** in the reaction of CH_4 with O_2.

(b) If 1000 moles of CH_4 are burnt as fuel, **complete the Table below**, given the molecular weight of CO_2 is 44, and that of CO is 28:

	Reaction A	**Reaction B**
Total energy released (kJ)		
Mass produced (kg)	**CO_2**:	**CO**:
Maximum electricity produced (MJ)		

(c) What factors may impact the maximum values of electricity you can generate from a fuel?