الـجـامـعـة الوطـنيـة
National University
Science & Technology للعلـوم والتكنـولوجيا
كليـة عمــان البحــرية الــدولية
International Maritime College Oman

Final Exam

PT – TPS: PROCESS SYSTEM SAFETY Fall 2024

Points of attention:

- For each question, the maximum earned points are specified in the question.
- Write clearly! Answers that are not readable are not marked and don't earn marks!
- All answers should be written in English using **blue or black pens** only.
- Use the pencil only for diagrams and graphs.
- Show all the calculation steps in the given space.
- When finished, submit the question paper, together with the answer scripts and the signed cover page to the invigilator.
- Any cheating/copying may result in an instant failing of the examination.

Exam Duration: 2:30 hours
Instructor's Name: Dr. Aldrin Karunaharan
Exam Date: 08/01/2025
Program: PE

	40
	10

Student Information			
Name:		ID:	
Signature:			

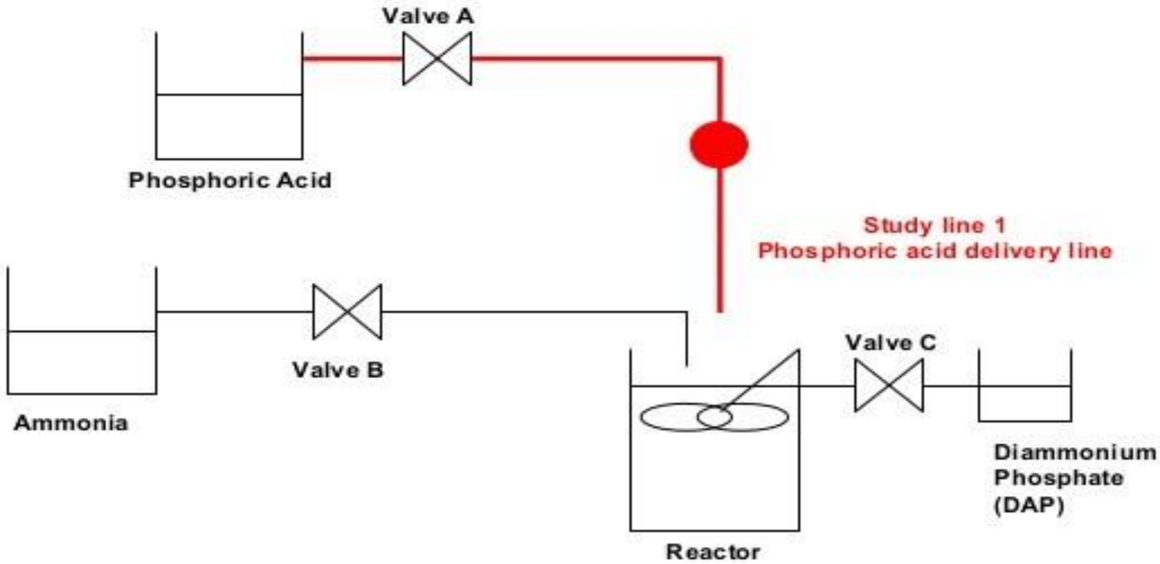
Invigilator		
Initials:		☐ Student ID checked
Time received:		

ANSWER ALL THE QUESTIONS

Q1. Apply risk assessment principles to evaluate the risks and associated hazards for the task of repairing a high-voltage switch gear in an underground cell with a diameter of 4 feet and a depth of 20 feet. Formulate a standard risk assessment table for the task by computing the risk index and proposing control measures for any six recognized hazards. [6 marks]

Q2. In a gas flare system used in chemical plants, released gases are burned as they exit the flare stacks to decompose them in the air and reduce emissions. Draw a block flow diagram of the gas flare system and justify the purpose of each unit within the system. Identify and explain two major hazards associated with this operation. [5 marks]

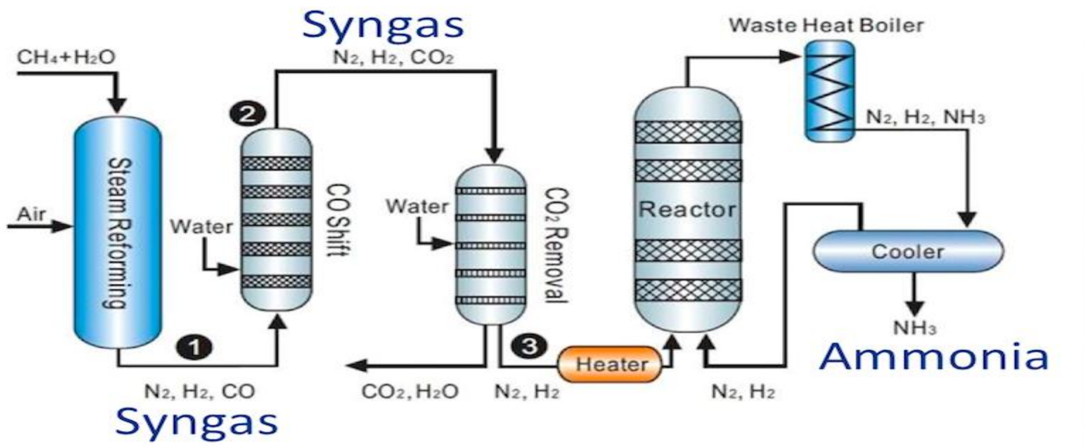
Q3. Apply the "What If" technique for the DAP [Di ammonium Phosphate Reactor] given below and complete the "What If" table. [4 marks]



Crowl. D,(2012)

No.	What if	Consequences/Hazards	Control actions
1.			
2.			
3.			
4.			

Q4. Using the HAZOP (Hazard and Operability) study technique, analyze the potential hazards in an ammonia reactor and complete the provided HAZOP table. [6 marks]



(Alina Green, 2022)

No.	Parameter	Deviations	Consequences	Possible causes	Control measures
1.					
2.					
3.					
4.					

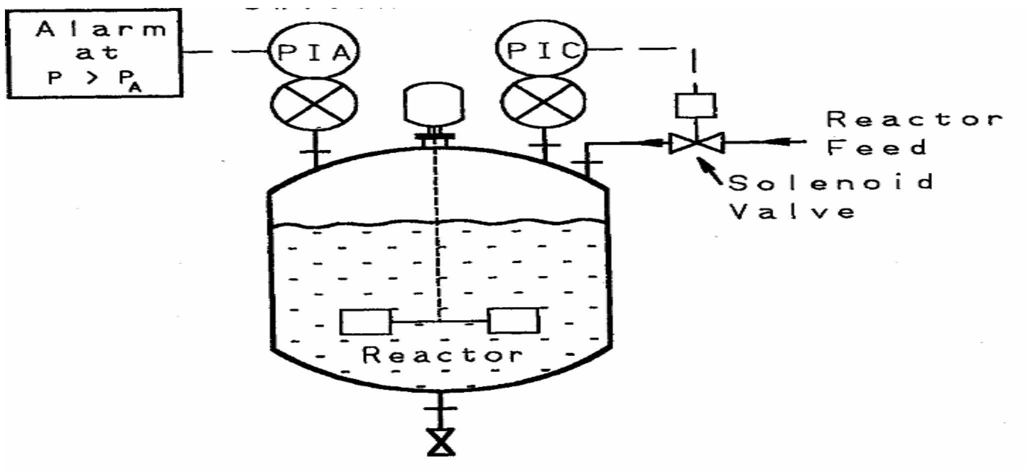
Q5. A 1-inch hole develops in a tank containing nitrogen at 200 psi and 80°F. Calculate the mass flow rate escaping from the tank using the provided data. [4 marks]

Gas Constant R_g	1545 ft lb_f/ft-mole^{0}R
γ Discharge coefficient	1.41
Flow coefficient C	1.0
Molecular weight of nitrogen M	28 lb_m/lb-mole
Gravity g_c	32.17 ft $lb_m/lb_f s^2$

Q6. Propose safety control measures for **any ONE** of the following operations. Include diagrams where applicable. [5 marks]

a) A reactor used to produce phosgene via the gas-phase reaction of carbon monoxide and chlorine
b) An exothermic reaction process regulated by cooling water.

Q7. Perform a process hazard analysis (PHA) for the reactor described below using the fault tree analysis. Illustrate your analysis with a fault tree diagram to show potential fault scenarios. [3 marks]



Crowl. D,(2012)

Q8. Read the case study of the accident given below and recommend five appropriate engineering control measures to prevent such type of accident in the future. [4 marks]

In 2008, a tragic incident occurred at a chemical plant in West Virginia involving a runaway reaction during the production of a pesticide. The process involved a high-temperature, high-pressure reaction that required precise temperature control. On that day, a cooling system failure allowed temperatures to rise beyond safe limits, causing an uncontrolled exothermic reaction that led to a violent explosion. The blast resulted in a fire and a massive release of toxic chemicals. Tragically, two workers who were nearby at the time of the explosion lost their lives, and several others sustained injuries.

An investigation revealed that the plant had not installed certain automated shutdown systems that could have detected the temperature spike and halted the reaction in time. Additionally, safety protocols for manual shutdown were unclear and poorly communicated to the operators. The accident highlighted several key issues in the plant's safety culture, including inadequate training for workers on emergency response procedures and insufficient maintenance of critical systems like the cooling unit. The failure to recognize and address these vulnerabilities earlier in the plant’s operations was a crucial factor that contributed to the severity of the incident. The explosion not only resulted in loss of life and significant environmental damage but also triggered widespread regulatory reviews and changes in safety standards across the chemical manufacturing industry. This incident served as a stark reminder of the importance of proactive risk management, continuous safety training, and the integration of automated safety systems to prevent similar catastrophic events.

WSHC Case Studies in Chemical Industry, (2012)

Recommendations

1	
2	
3	
4.	

Q9. Air is compressed over liquid hexane, which has an auto-ignition temperature of 487°C, from an initial pressure of 25 psi to 600 psi. Assume the adiabatic index (γ) for air is 1.4, and the initial temperature is 90°F. Calculate the final temperature of the air after compression. Determine if this temperature could lead to an explosion. [3 marks]

Additional sheet

FORMULA SHEET

1. $(\text{TLV}-\text{TWA})_{\text{MIX}} = \sum_{I=1}^{n} \frac{C_i}{(\text{TLV}-\text{TWA})_i}$
2. $Q_V = \frac{Q_m R_g T}{K C_{ppm} PM} \times 10^6$
3. $C = \frac{Q_m^*}{\sqrt{2}\pi^{3/2}\sigma_x\sigma_y\sigma_z}$
4. $H_f = -60 d_f + 0.5\sqrt{(120 d_f)^2 - \left(\frac{4\pi q_f X_f^2 - 960 Q_m \sqrt{M}}{\pi q_f}\right)}$
5. $T_i = T_i \left(\frac{P_f}{P_i}\right)^{(\gamma-1)/\gamma}$
6. $(Q_f)_{\text{chocked}} = C_0 A P_0 \sqrt{\frac{\gamma g_c M}{R_g T_0}\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}$
7. $t_e = \frac{1}{C_0 g}\left(\frac{A_t}{A}\right)\sqrt{2 g h_L^0}$

   $C = \frac{Q_m^*}{\pi\sigma_y\sigma_z} exp(-\left(\frac{1}{2}\right)\left(\frac{Hr}{\sigma_z}\right)^2$
8. $Q_f = \frac{\beta}{\rho C_P} UA(T - Ta)$
9. $Q_m = \frac{\nabla H_v A}{V_{fg}}\sqrt{\frac{g_C}{T C_P}}$
10. $C_{ppm} = \frac{KAP\text{sat}}{Qv\, P} \times 10^6$

12. $f_v = \frac{C_P [T_O - T_b]}{\nabla H_v}$

MLO & Bloom's Level of Complexity

Q #	**MLO Addressed**	**Complexity Level**	**Mark**	**Remark**
Q1.	**MLO 2**	Applying	**6**	
Q2	**MLO 3**	Remembering/understanding	**5**	
Q3.	**MLO 4**	Analyzing	**4**	
Q4	**MLO 3**	Evaluation	**6**	
Q5	**MLO 2**	Application	**4**	
Q6	**MLO 1**	Application	**5**	
Q7	**MLO 3**	Analyzing	**3**	
Q8	**MLO 4**	Evaluation	**4**	
Q9	**MLO 3**	Application	**3**	
		Total	**40**	

References:

1. WSHC Case Studies Chemical Industry. 2013.
2. Daniel Crowl, A, and Joseph Louvar., (2011). Chemical Process Safety: Fundamentals with Applications, 2nd ed, Boston: Prentice Hall publications.