UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE : CEB4413 - GAS PROCESS ENGINEERING

DATE : 2 AUGUST 2024 (FRIDAY)

TIME : 9.00 AM - 12.00 NOON (3 HOURS)

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **NINE (9)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. Energy Plus Sdn. Bhd. has been supplying natural gas that contains 8% carbon dioxide and 5% hydrogen sulfide to your company. The gas has a specific gravity of 0.7 and Wobbe's Index of 1425 Btu/scf. Since the contract with Energy Plus Sdn. Bhd. will expire, ProGas Corporation and Petro Group have submitted their proposal to be the new natural gas supplier for your company. The compositions of their natural gas are given in **TABLE Q1**.

TABLE Q1: Natural gas compositions

Components	Molecular weight (lb/lbmol)	Higher heating value (Btu/scf)	Lower heating value (Btu/scf)	Mole fraction	
				ProGas Corporation	Petro Group
Methane	16.04	1010	909	0.874	0.888
Ethane	30.07	1770	1619	0.083	0.053
Propane	44.10	2516	2315	0.021	0.036
i-Butane	58.12	3252	3000	0.005	0.008
n-Butane	58.12	3262	3011	0.002	0.006
i-Pentane	72.15	4001	3699	0.003	0.005
n-Pentane	72.15	4009	3704	0.006	0.004
n-Hexane	86.18	4756	4404	0.001	0
n-Heptane	100.2	5503	5100	0.001	0
Nitrogen	28.02	0	0	0.001	0
Carbon dioxide	44.01	0	0	0.002	0
Hydrogen sulfide	34.08	637	587	0.001	0

a. Estimate the density of the natural gas that has been supplied by Energy Plus Sdn. Bhd at 1500 psia and 750°R.

[13 marks]

b. Evaluate the properties of the natural gas from ProGas Corporation and Petro Group and recommend the supplier that should be selected for the new contract, if it is desired to use the natural gas with the existing appliances and valve settings in your company.

[12 marks]

2. You are assigned to design an offshore based separator for a reservoir fluid having a low gas-oil ratio of 5800 SCF/bbl. The properties of the fluid and the operating conditions of the separator are given in **TABLE Q2**.

TABLE Q2: Operating conditions of the separator

Gas rate	16 MMSCFD
Gas specific gravity	0.6
Oil gravity	35° API
Operating pressure	1100 psia
Operating temperature	70°F
Gas viscosity	0.013 cp

a. Design vertical and horizontal separators for the process **AND** recommend the design that should be applied with appropriate justifications. Use $C_d = 1.1$ as your first assumption.

[24 marks]

b. Based on your selected design in **part (a)**, estimate the maximum gas and oil capacities that can be operated in the separator if all the other operating conditions are unchanged. Calculate the corresponding gas-oil ratio of the process with the maximum gas and oil capacities.

[6 marks]

3. a. Natural gas from a reservoir contains 9% carbon dioxide and trace amounts of hydrogen sulfide. It is desired to reduce the amount of carbon dioxide in the natural gas to 1% only to meet the retail quality. Based on the selection chart in **APPENDIX**, propose an appropriate sweetening process to achieve the desired natural gas composition and illustrate the process flow with the aid of schematic diagram. Given that the pressure of the gas is 750 psia.

[10 marks]

b. A natural gas having a specific gravity of 0.65 enters a pipeline at 150°F and 600 psia. The gas eventually cooled down to 40°F due to heat losses before it exits the pipeline at 18 MMSCFD. The gas carries along 1500 lb/day of water and 500 bbl/day of condensate with an average density of 300 lb/bbl.

i. If propylene glycol is used to prevent hydrate formation in the pipeline, estimate the amount of propylene glycol required. Given that the solubility of propylene glycol in condensate is 0.45% by weight, while the ratio of lb of propylene glycol in vapor per MMSCF of gas to the weight percent of propylene glycol in water is 0.88.

[10 marks]

ii. Evaluate the effectiveness of using propylene glycol as an inhibitor based on its amount that is lost in the condensate and in the vapor, compared to the amount that actually contributes to the treatment. Propose a strategy to improve the economics of propylene glycol application as chemical inhibitor.

[5 marks]

$$L_s = L_g + \frac{D}{12}$$

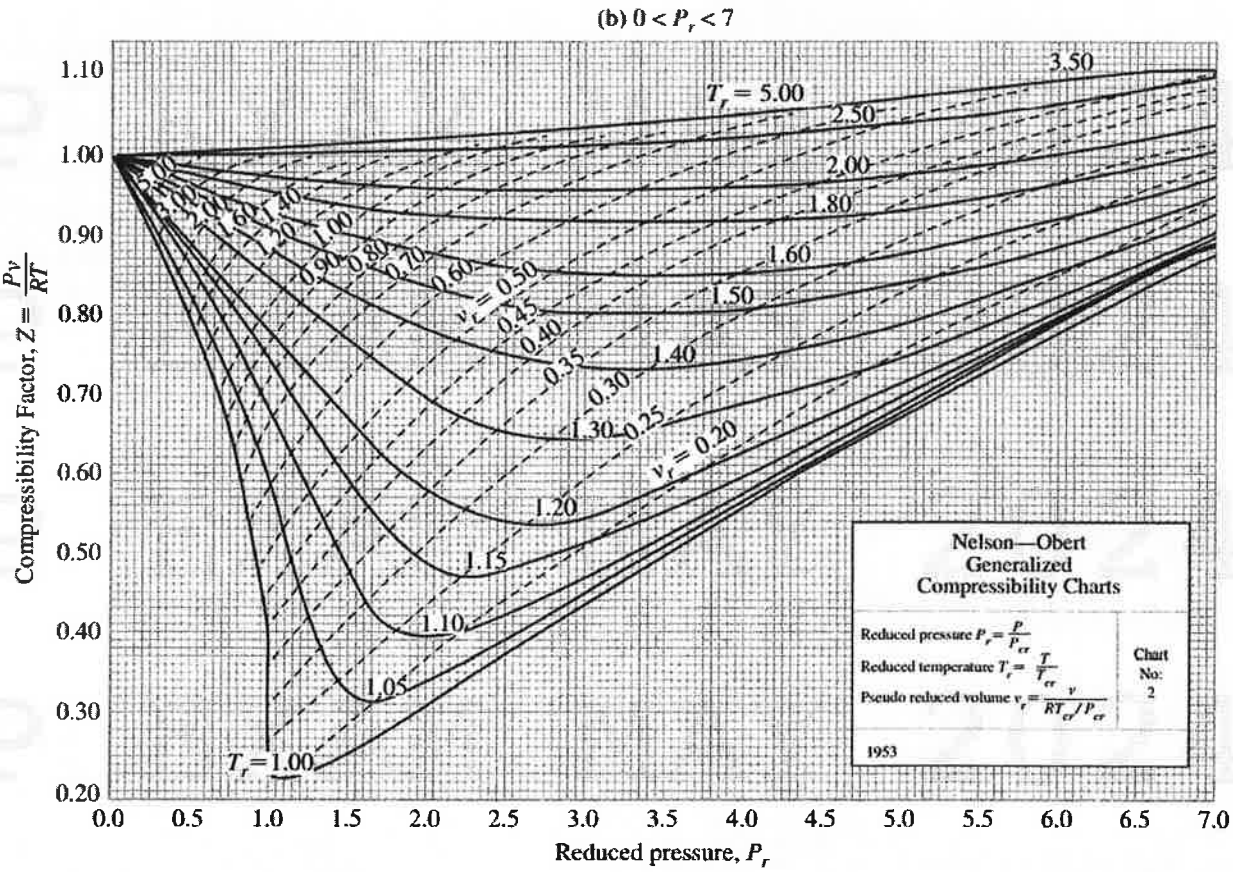
$$L_s = \frac{4}{3}L_o$$

Hydrate inhibition model

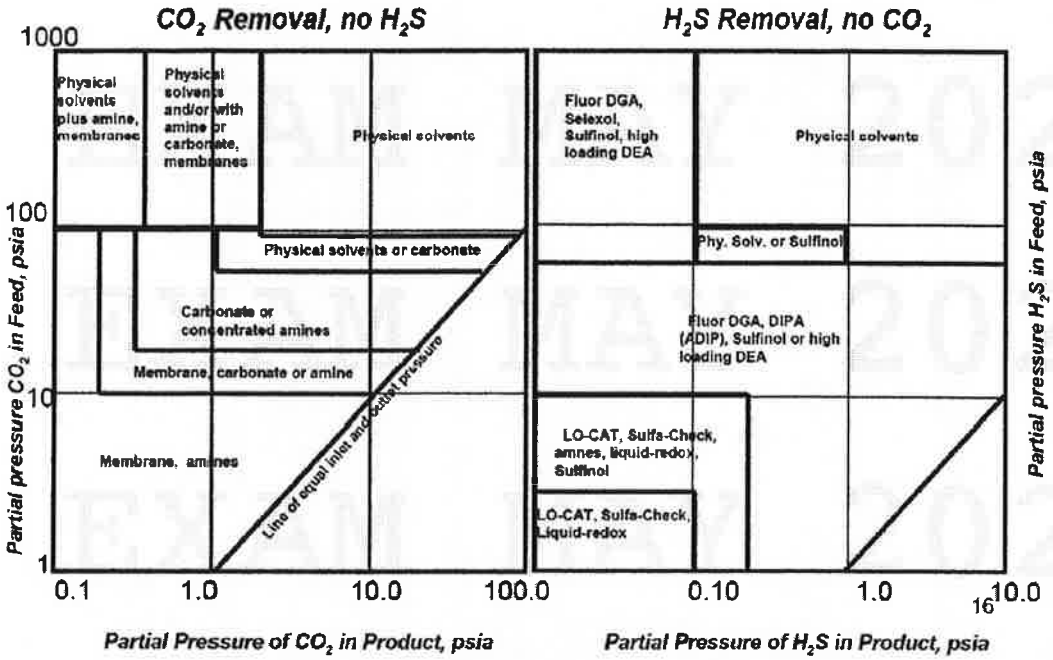
$$\Delta T = \frac{KW}{M(100 - W)}$$

Properties of chemical inhibitors

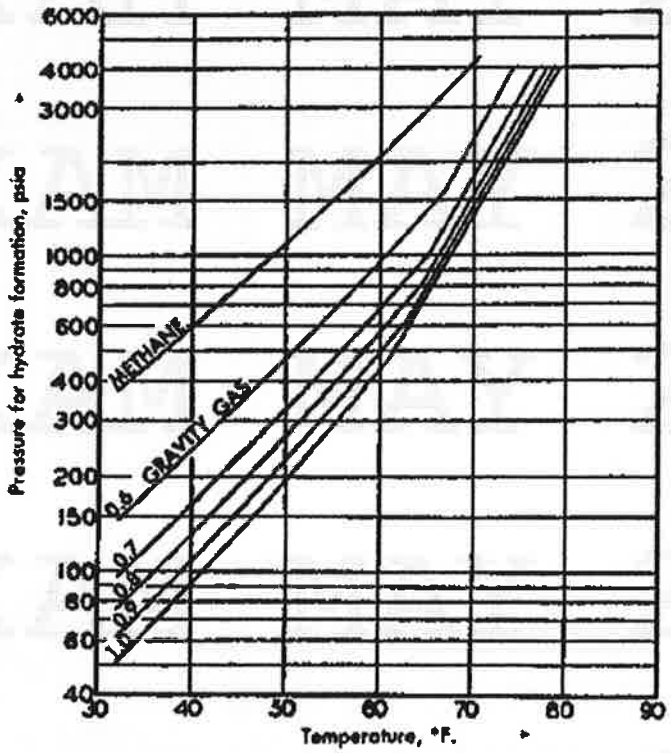
Inhibitor	M	K
Methanol	32.04	2335
Propylene glycol	76.10	3590



Compressibility factor chart



Sweetening process selection chart



Pressure-temperature curves for hydrate formation prediction