UNIVERSITY OF ABERDEEN SESSION 2016-17

EG5099

Degree Examination in EG5099 Upstream Oil and Gas Processing

Tuesday 6 December 2016 2.00 – 5.00pm

PLEASE NOTE THE FOLLOWING

(i) You **must not** have in your possession any material other than that expressly permitted in the rules appropriate to this examination. Where this is permitted, such material **must not** be amended, annotated or modified in any way.

(ii) You **must not** have in your possession any material that could be determined as giving you an advantage in the examination.

(iii) You **must not** attempt to communicate with any candidate during the exam, either orally or by passing written material, or by showing material to another candidate, nor must you attempt to view another candidate's work.

(iv) You **must not** take to your examination desk any electronic devices such as mobile phones or other "smart" devices. The only exception to this rule is an approved calculator.

Failure to comply with the above will be regarded as cheating and may lead to disciplinary action as indicated in the Academic Quality Handbook.

Notes: (i) Candidates *ARE/~~ARE NOT~~ permitted to use an approved calculator

(ii) Candidates *~~ARE~~/ARE NOT permitted to use Engineering Mathematics Handbook

(iii) Candidates ARE NOT permitted to use GREEN or RED pen in their exam booklet.

Attempts ALL questions

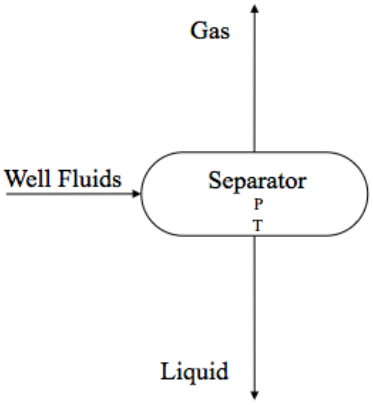
Each question is worth 20 marks.

Question 1

a) Sketch a typical mixed hydrocarbon gas phase envelope. Indicate the cricondenbar. What is the significance of the Cricondenbar for the operation of gas pipeline systems?

[4 marks]

b) For a two-phase separator operating at temperature T and pressure P indicate on a typical multicomponent hydrocarbon phase envelope the location of temperature T and pressure P for the gas and liquid streams.



[4 marks]

c) A final stage oil and gas separator is operating at 85 ^{o}C and 1.6 bara producing a crude oil product with a true vapour pressure (TVP) of 0.85 bara at 37.8 ^{o}C. Explain what will happen to the TVP of the crude oil if;

i) the separator temperature reduces and the pressure is held constant

ii) the separator pressure reduces and the temperature is held constant

[4 marks]

d) The standard and cubic form of the SRK equation of state and the associated fugacity coefficient expression are as follows. Describe the steps required to use these expressions to calculate the saturation temperature (boiling point) at a given pressure for a single component.

$$P = \frac{RT}{(V-b)} - \frac{a\alpha}{V(V+b)}$$

$$z^3 - z^2 + (A - B - B^2)\, z - AB = 0$$

Where;

$A = (a\alpha P)/(R^2T^2) = 0.42748\alpha P_r/T_r^2$

$B = (b\,P)/(RT) = 0.08664P_r/T_r$

$a = \Omega_a R^2T_c^2/P_c = 0.42748R^2T_c^2/P_c$

$b = \Omega_b RT_c/P_c = 0.08664RT_c/P_c$

$\sqrt{\alpha} = 1 + m(1 - Tr^{0.5})$ where

$m = 0.48 + 1.574\omega - 0.172\omega^2$

ω is the acentric factor, usual notation applies for other variables.

Fugacity Coefficient Φ is expressed as;

ln Φ = z - 1 - ln (z - B) - A/B ln (1 + B/z)

[8 marks]

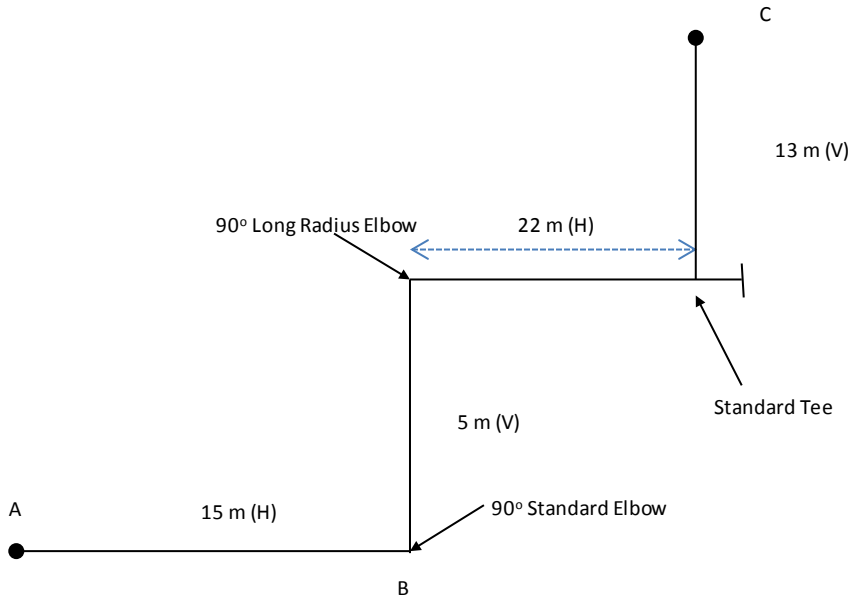
Question 2

a) Describe the concept of equivalent length as used in piping system pressure drop calculations.

[2 marks]

b) An oil (density, ρ = 800 kg/m^3, viscosity, μ = 0.003 Pa.s flows from A to C in a pipe with an inside diameter of 0.1 m. The pressure loss from A to C is 200100 Pa. Given the following information calculate the volume flowrate of oil in m^3/s.

System sketch with distances in metres. H is a horizontal section, V is a vertical upward section.



Darcy's equation applies (usual notation) $$\Delta P = \frac{\rho \cdot f \cdot L \cdot v^2}{2 \cdot D}$$

For turbulent flow the Blasius expression for friction factor applies, $f = 0.316/Re^{0.25}$

Pipe Fitting			Equivalent Length in Pipe Diameters (L/D)
Fittings	90° Standard Elbow		30
	45° Standard Elbow		16
	90° Long Radius Elbow		20
	90° Street Elbow		50
	45° Street Elbow		26
	Square Corner Elbow		57
	Standard Tee	Flow through run	20
		Flow through branch	60
	Close Pattern Return Bend		50

[8 marks]

c) The work done in compressing a gas can be expressed as;

$$\Delta H = \int V dP = -W_{theor}$$

For an isentropic compression process the following expression holds;

$$P \cdot V^k = const = P_1 \cdot V_1^k$$

Using these relations and the gas law expression incorporating compressibility to show that the isentropic enthalpy change can be expressed as;

$$\Delta H = \frac{m \cdot Z_1 \cdot R \cdot T_1}{\left(\frac{k-1}{k}\right) \cdot MW} \cdot \left(\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1 \right)$$

Usual notation applies.

[6 marks]

d) For a centrifugal compressor describe the condition known as surge.

[4 marks]

Question 3

a) A glycol dehydration system is used to remove water from a gas stream. Describe the operating principles and main components of a glycol system including the regeneration system. A sketch may help.

[6 marks]

b) Sketch a typical refrigeration cycle on a pressure enthalpy Mollier chart. Indicate the four key components of a refrigeration cycle. Show both isotherms and isentropic lines.

[6 marks]

c) Water saturated methane gas enters a tri-ethylene glycol (TEG), counter flow, gas dehydrator absorber operating at 30 ^{o}C and 70 bara. It is required to produce a product gas with a water content of 35 mg/Sm^3 from the absorber. Using the attached water saturation and equilibrium charts calculate the TEG concentration required to achieve this water content.

[4 marks]

d) A seawater deaeration column utilising nitrogen gas in a single stage, packed stripping column is in operation. You are asked to determine the height of a transfer unit. Describe how you would undertake this task.

[4 marks]

Question 4

The following oil, gas, water separation and associated compression arrangement has been proposed for an offshore development. It is a single process train comprising two stages of three phase separation with interstage heating.

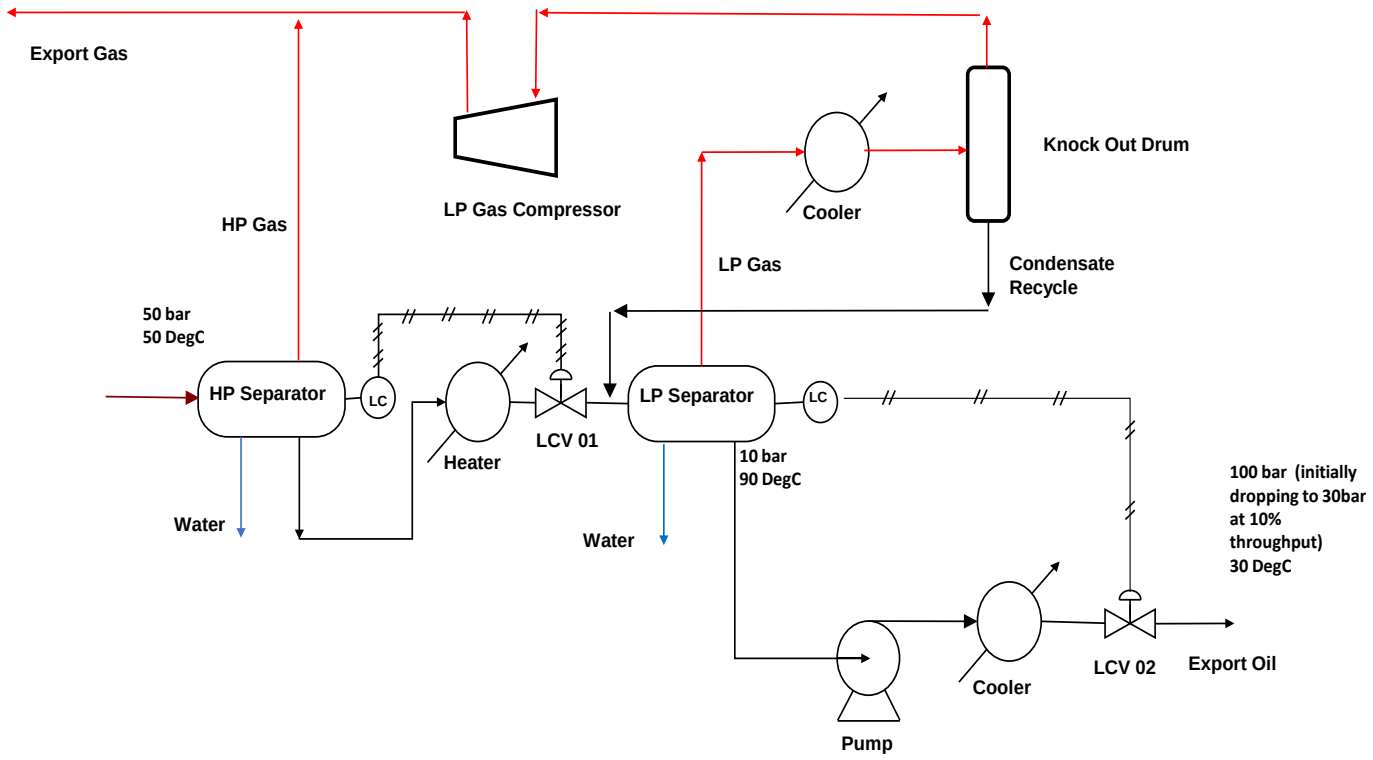
An export pump and cooler deliver the oil to an export pipeline. The export pump is driven by a fixed speed electric motor in a 2 x 100% parallel configuration. The pump efficiency at design conditions is 70%

Large quantities of hot water are produced from each separator.

The interstage heater is an electric unit. Electrical supply to the heater, pump and compressor is from a simple cycle, gas turbine coupled to an alternator – the gas turbine is fuelled by process gas.

The system is designed for a 100% throughput but as the development ages, flowrates will drop progressively to 10% of design. The initial discharge requirement from the pump is 100 bara, but as the throughput reduces, the back pressure from the pipeline reduces requiring less pump discharge pressure.

Gas from the LP separator is cooled and passed to a knock out drum. The liquids from the drum are recycled to the inlet of the LP Separator. The gas is compressed in a 1x100% LP centrifugal compressor to a pressure equal to the HP Gas. The compressor is driven by a fixed speed electric motor and controlled by an anti-surge recycle system. The compressor polytropic efficiency is 70%.



Review this arrangement from an energy efficiency standpoint, identifying 10 topics (2 marks each) which you would recommend require investigation before the design is finalised. For each topic identified give a short description of why you think it is worthy of consideration.

[20 marks]

Question 5

a) Describe a hydrate and the conditions necessary for their formation.

[2 marks]

b) In a fully mixed, non-flowing pipeline it is important to be able to predict the rate of temperature loss with time. By conducting a heat balance over a pipeline segment show that the rate of temperature decay is given by the following expression.

$$T = Tw + (Ti - Tw)\, e^{-\frac{UA}{mCp}.t}$$

Where
m = mass of fluid within segment (kg)
C_p = specific heat capacity of fluid (J/kg ^{o}C)
U = overall heat transfer coefficient (W/m^2 ^{o}C)
A = area of pipe (m^2)
T_w = temperature of surroundings (^{o}C)
T_i = initial temperature at time zero (^{o}C)
T = average bulk fluid temperature at time t (^{o}C)
t = time (s)

[8 marks]

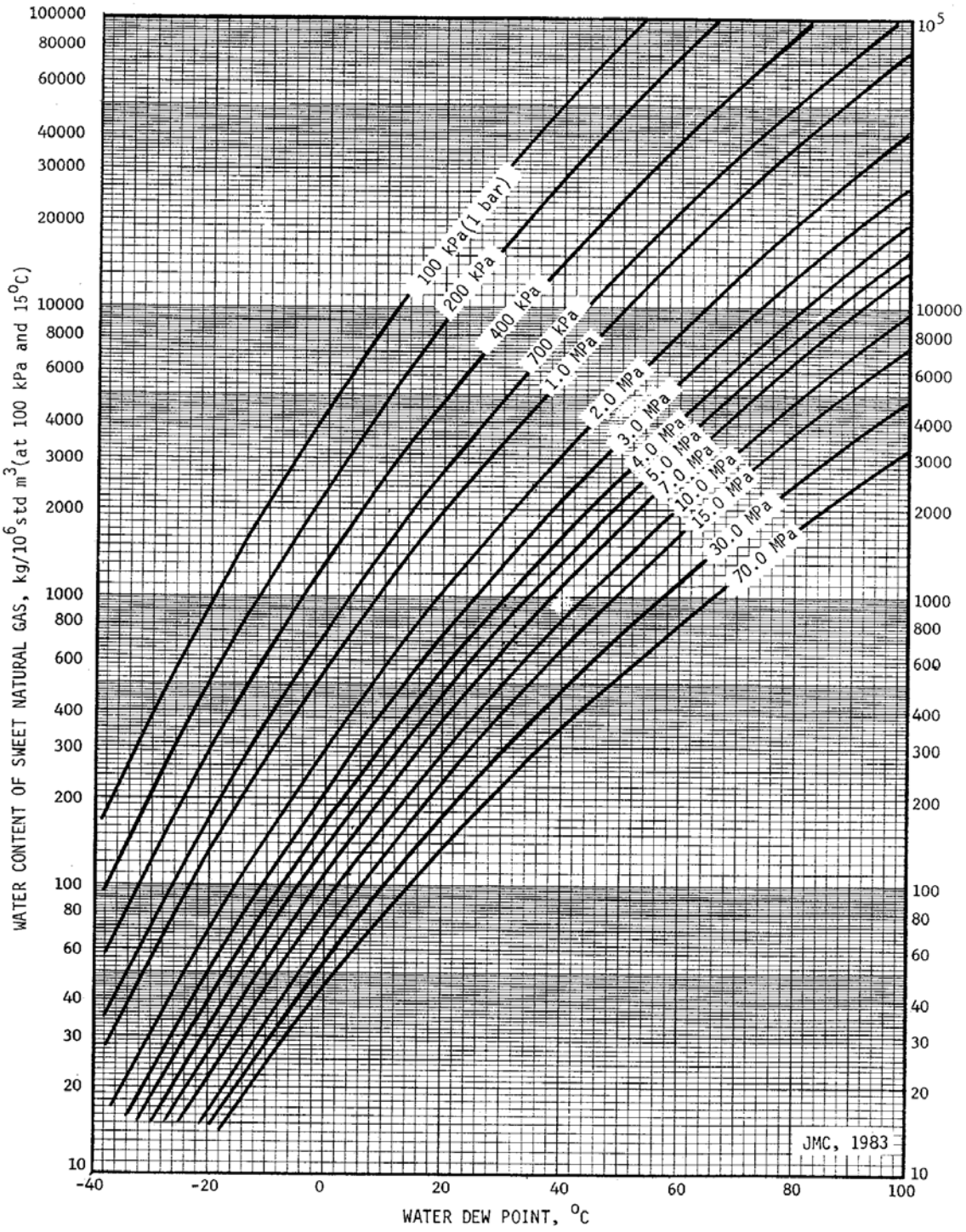
c) A wax is characterised by cloud point and pour point. Describe the meaning of both terms.
[4 marks]

d) Describe the phenomenon, and the conditions which promote, severe slugging in a pipeline, vertical riser system.
[6 marks]

END OF PAPER

Figures and charts

Question 3c Water Saturation Chart



Question 3c TEG Equilibrium Chart