UNIVERSITY OF ABERDEEN SESSION 2017-18

EG5099

Degree Examination in Upstream Oil and Gas Processing

Tuesday 5 December 2017 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 permitted to use an approved calculator

(ii) Candidates ARE permitted to use Engineering Mathematics Handbook

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

(iv) Data sheets are attached to the paper.

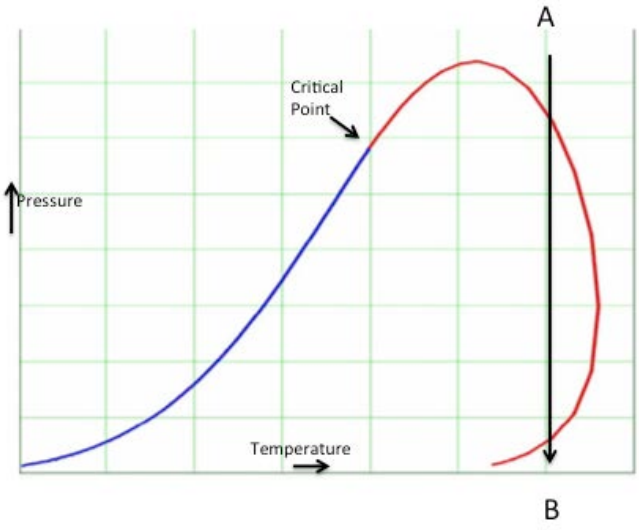
Attempts ALL 5 questions.

Each question is worth 20 marks.

Question 1

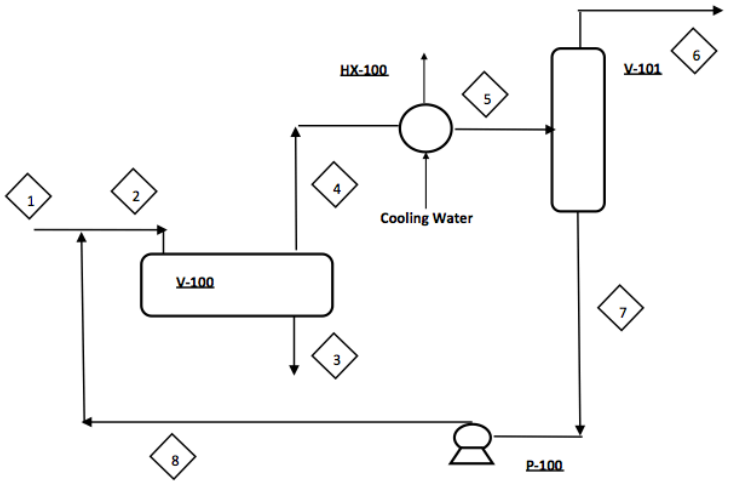
a) The following is a generic, multi-component hydrocarbon phase envelope. Describe the phase states in the isothermal transition from A to B. Pay particular attention to gas to liquid ratios.

[6 marks]



b) Stream 1 on the following figure is a two-phase hydrocarbon mixture at pressure P_1 and T_1, it is mixed with recycled condensate (8) also at pressure P_1 and fed to a two-phase separator V100 at temperature T_2, controlled at pressure P_2. The gas evolved (4) is taken to a cooler (HX001) where it is cooled to T_3. The pressure drop across the exchanger is ΔP. Stream 5 enters a two-phase separator V101 operating at the same pressure as HX-100 outlet. The gas stream (6) moves to another part of the process. The liquid from V101 (7) feeds the recycle pump P100, which increases the pressure of the liquid to P_1. On a generic, mixed hydrocarbon phase envelope, indicate the temperature and pressure position of streams 1,4,5,7 and 8. Explain your reasoning for the positions identified. Assume that pipework friction and elevation effects are negligible.

[10 marks]



c) You have completed a heat and mass balance using a cubic equation of state and find that one of the unit operations is operating in the two phase region close to the critical point. Comment on your confidence on the accuracy of the predicted properties produced by the simulator for that particular unit operation.

[4 marks]

Question 2

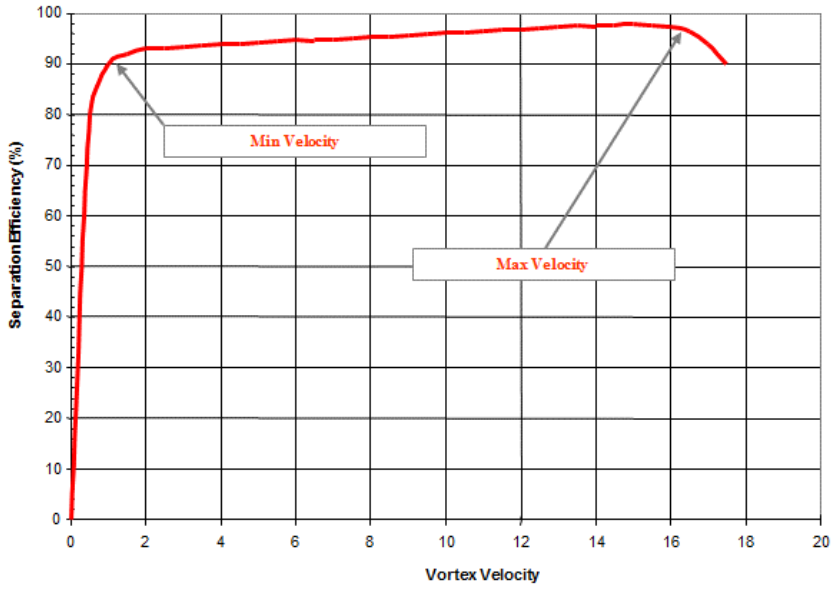
a) A liquid phase mixture of propane, n-butane and n-pentane is pipeline transported. The pipeline route can be simplified into two segments each 3000 m long. The first segment rises to a height of 500 m, the second dropping 500 m back to the same level as the pipeline inlet. The pipeline entry temperature is 80 ^{o}C, the inlet pressure is 3000 kPa. The flowrate is 2500 kmol/hr and the mole fractions of the components propane, n-butane and n-pentane are 0.4, 0.3 and 0.3 respectively. The density is 496 kg/m$^{3.}$ The internal diameter of the pipe is 250 mm. The pipeline is highly insulated, hence flow can be assumed to be isothermal. Pipeline production will be curtailed if vapour forms at the pipeline apex. Using the attached equilibrium K factors determine whether vapour will form at the apex. State any assumptions. Hint - some information provided may be superfluous.

[10 marks]

b) A hydrocyclone is used to remove oil droplets from a continuous water phase. Describe the operating principles of a hydrocyclone.

[6 marks]

c) Typical separation performance of a hydrocyclone is shown as follows. Explain what is happening at low and high vortex velocities which would cause separation efficiency to drop.



Hydrocyclone Separation Efficiency

[4 marks]

Question 3

a) A three phase oil, gas, water gravity separator with no internals is producing an oil product which meets the required water specification without the use of demulsifiers. New wells are introduced to the separator from a different reservoir that has a higher oil viscosity and density. Furthermore the new wells have downhole electric submersible pumps. It is found that the introduction of these new wells causes the water in oil content to increase and exceed specification. Identify four reasons why the water in oil content increases.

[4 marks]

b) You are requested to investigate means for improving the water in oil content. Give six approaches to improve oil water in oil content.

[6 marks]

c) As part of a carbon capture scheme, a CO_2 compression system is required to deliver CO_2 at 100 bara and 30 ^{0}C. The CO_2 is captured from a gas turbine flue gas using amine absorption. The CO_2 is delivered from the amine regenerator to the first compressor at 1 bar and 40 ^{0}C. The gas turbine uses methane as fuel and has a combustion efficiency of 48%. The output from the turbine is 400 MW. Using the attached CO_2 Mollier chart estimate the number of compression stages and power required by the CO_2 compression system. As a first approximation assume the calorific value of methane is 40 MJ/kg, the compressors operate isentropically and that the maximum compressor outlet temperature from each stage of compression is 150 ^{0}C. Cooling water is available at 20 ^{0}C. State any other assumptions. Enclose your Mollier chart including your student number with the returned exam paper.

[10 marks]

Question 4

a) A process gas is to be cooled from 20 ^{o}C to -35 ^{o}C using a refrigeration plant. The refrigerant is propane. Using the attached Mollier chart for propane estimate the compressor energy savings between a one and a two stage refrigeration system. Assume air is available at 25 ^{o}C for condensation. State any other assumptions.
Enclose your Mollier chart including you student number with the returned exam paper.

[14 marks]

b) State and explain six factors in deciding whether to use a one or two stage refrigeration system

[6 marks]

Question 5

a) Sketch and describe four common multi-phase flow patterns that might occur in a horizontal pipeline transporting a mixture of gas and oil.

[4 marks]

b) Gas and liquid are flowing in a vertical pipe of diameter D_1. Pressure drop readings are taken across the pipe and recorded as ΔP_1. The pipe diameter is increased to D_2, the gas and liquid rate remains the same and the pressure drop reduces from ΔP_1 to ΔP_2. A further increase in pipe diameter to D_3 is made. The gas and liquid rate remains the same but this time the pressure drop increases from ΔP_2 to ΔP_3. Explain the reason for the observed pressure drop trend?

[8 marks]

c) A downward sloping, 1200m long pipeline with an internal diameter of 0.292m joins a 100m long vertical pipe (riser) of the same diameter. The pipeline contains oil, gas and water flowing at an average pressure of 25 bara. The flow rates are:

Oil = 0.005 m^3/s
Water = 0.005 m^3/s
Gas = 0.041 m^3/s

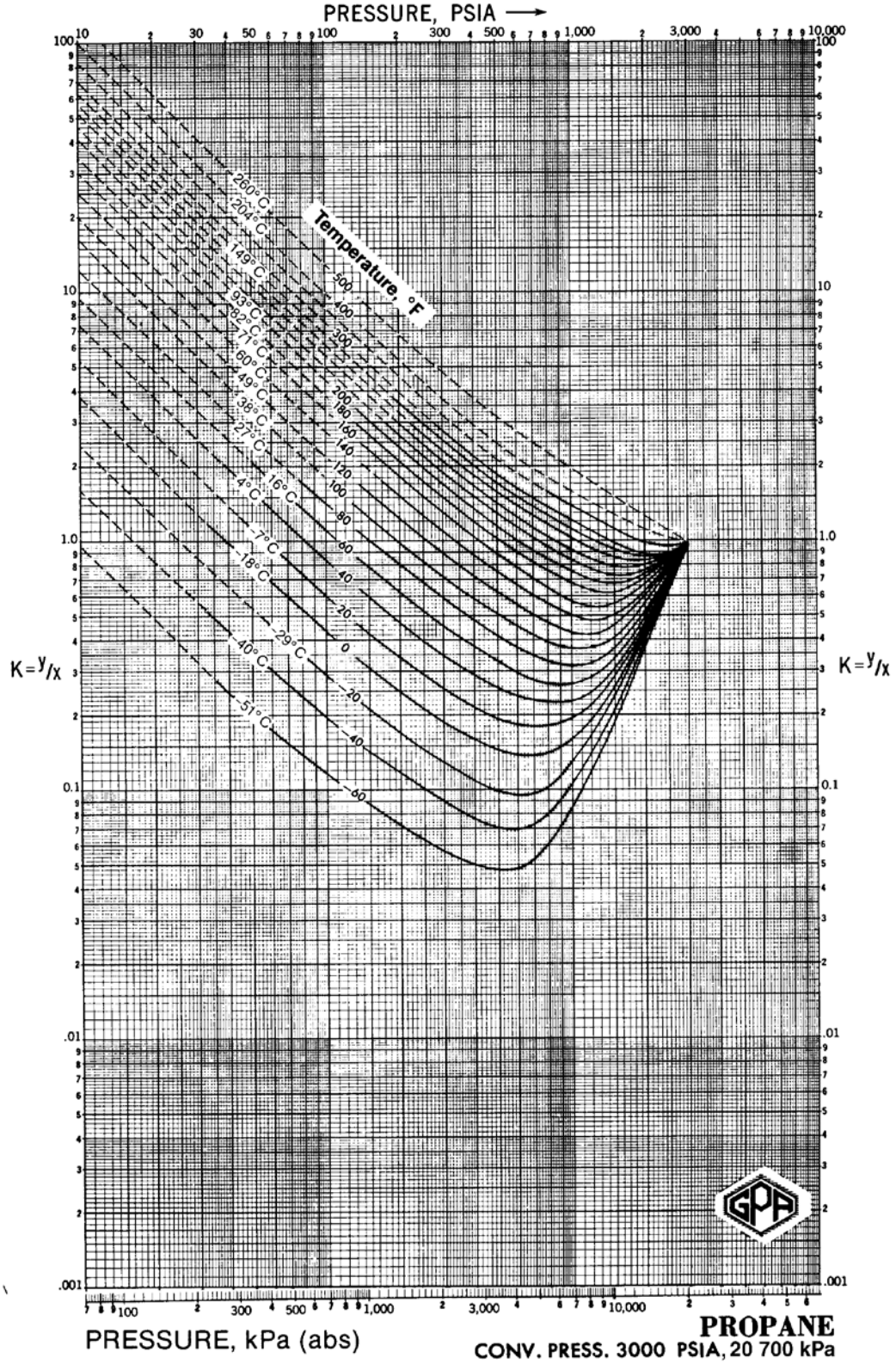
The oil and water densities are 850 and 1000 kg/m^3 respectively.
Determine if the system of pipeline and riser will be prone to severe slugging at the given flowing conditions. Hint: calculate the maximum rate of pressure rise in the vertical riser and compare that with the rate of pressure rise of the gas portion of the pipeline. State your assumptions.

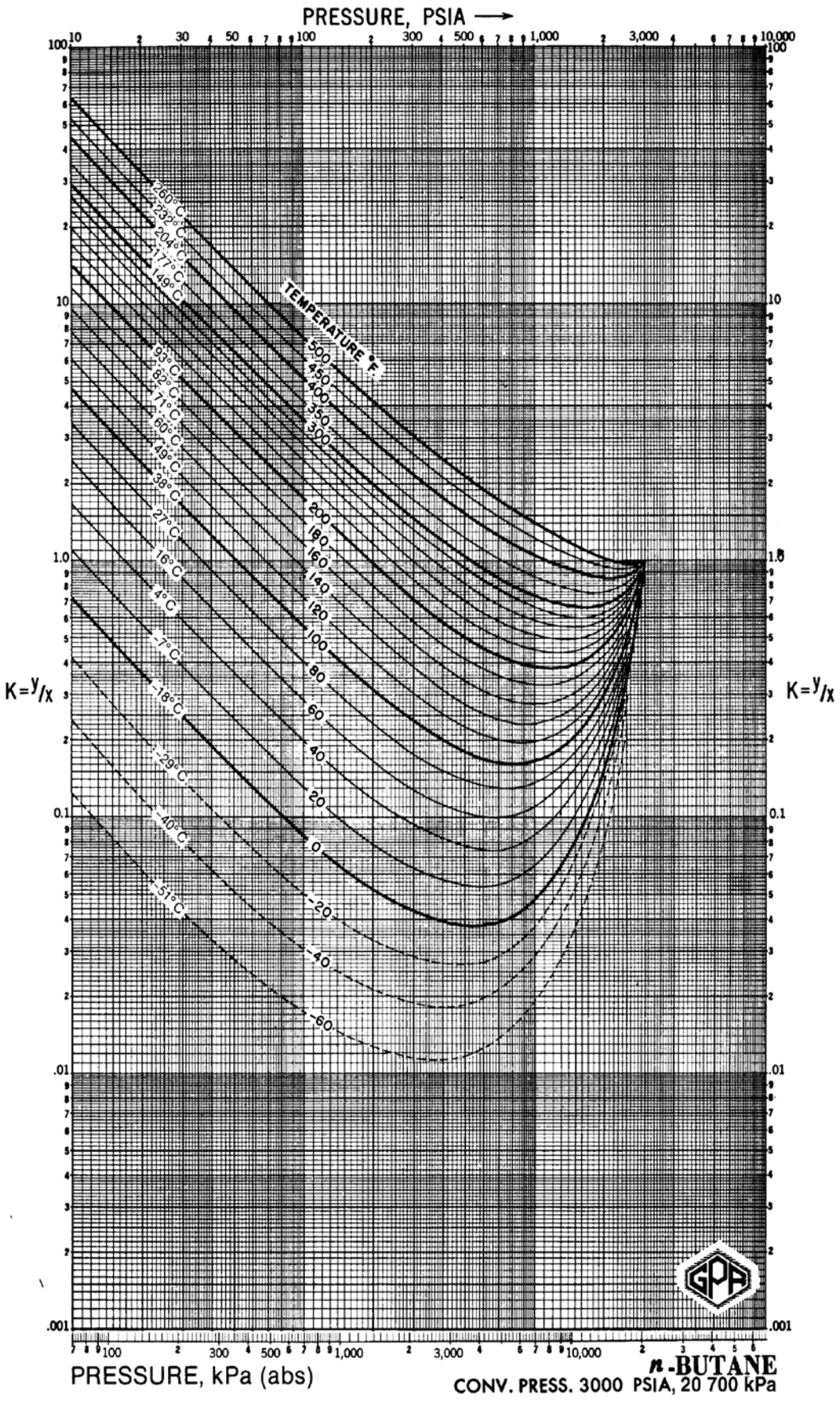
[8 marks]

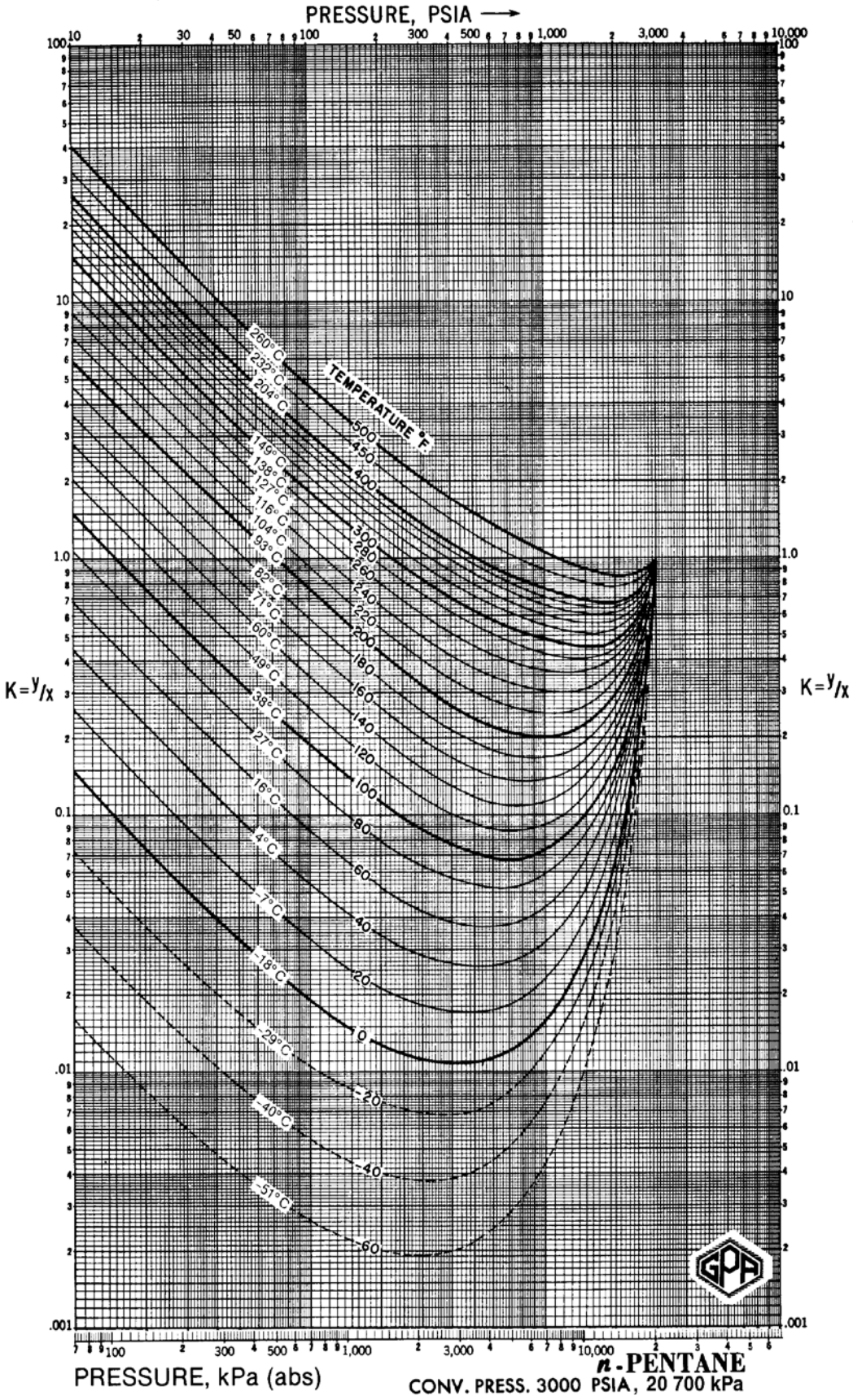
END OF PAPER

Figures and charts

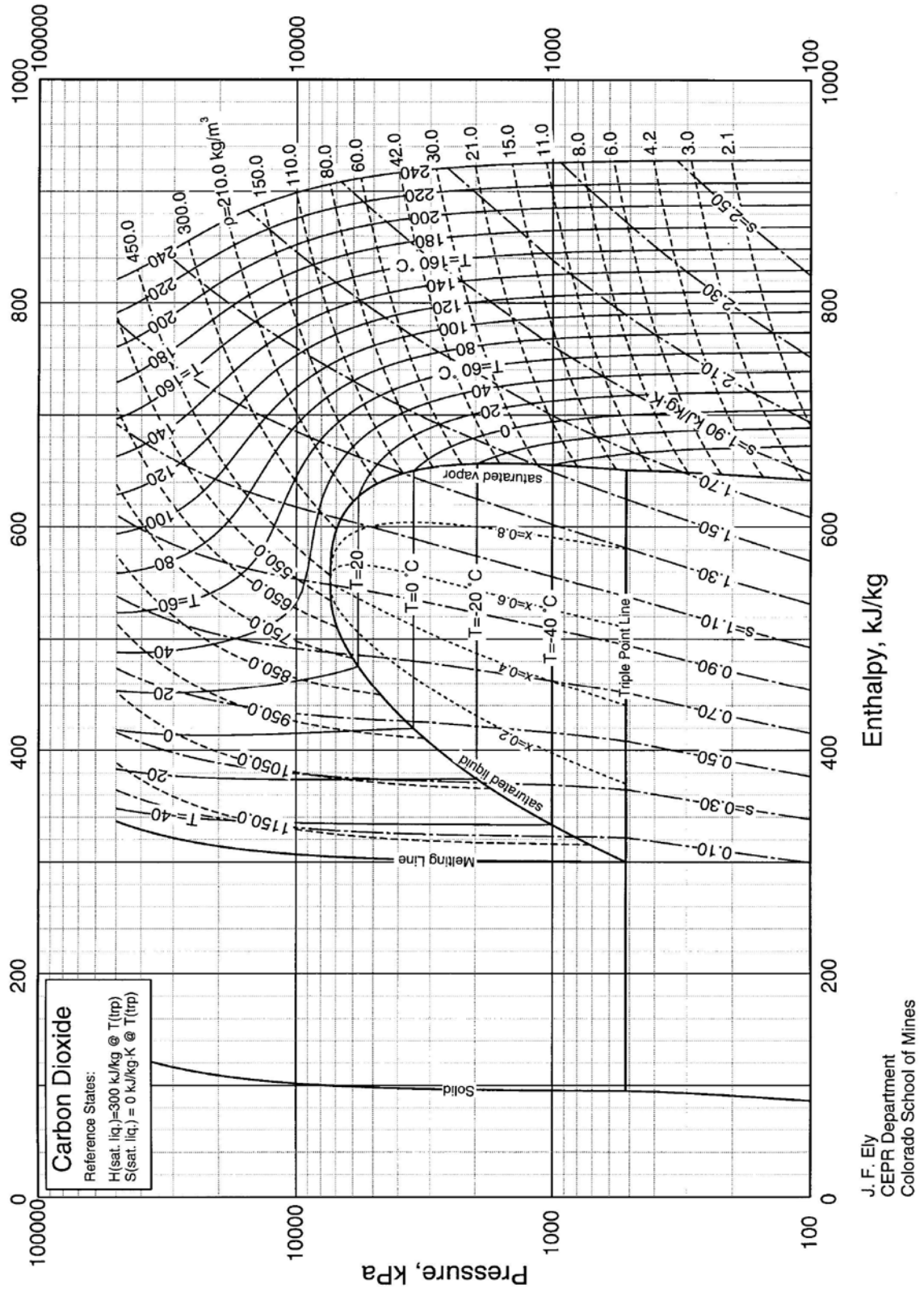
Question 2 a – K Equilibrium Ratios




PRESSURE, PSIA
TEMPERATURE °F
K=y/x
PRESSURE, kPa (abs)
n-BUTANE
CONV. PRESS. 3000 PSIA, 20 700 kPa
GPA


PRESSURE, PSIA
TEMPERATURE °F
K=y/x
PRESSURE, kPa (abs)
n-PENTANE
CONV. PRESS. 3000 PSIA, 20 700 kPa
GPA

Question 3c – CO_2 Mollier Chart



Question 4a – Propane Mollier chart