UNIVERSITY OF ABERDEEN SESSION 2018–19

EG5099/EG503H

Degree Examination in EG5099/EG503H Upstream oil and gas processing

12th December 2018 9 am – 12 pm

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 NOT permitted to use the 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.

Candidates must attempt *ALL* questions. All questions are worth 20 marks.

Question 1

Phase behavior and physical properties

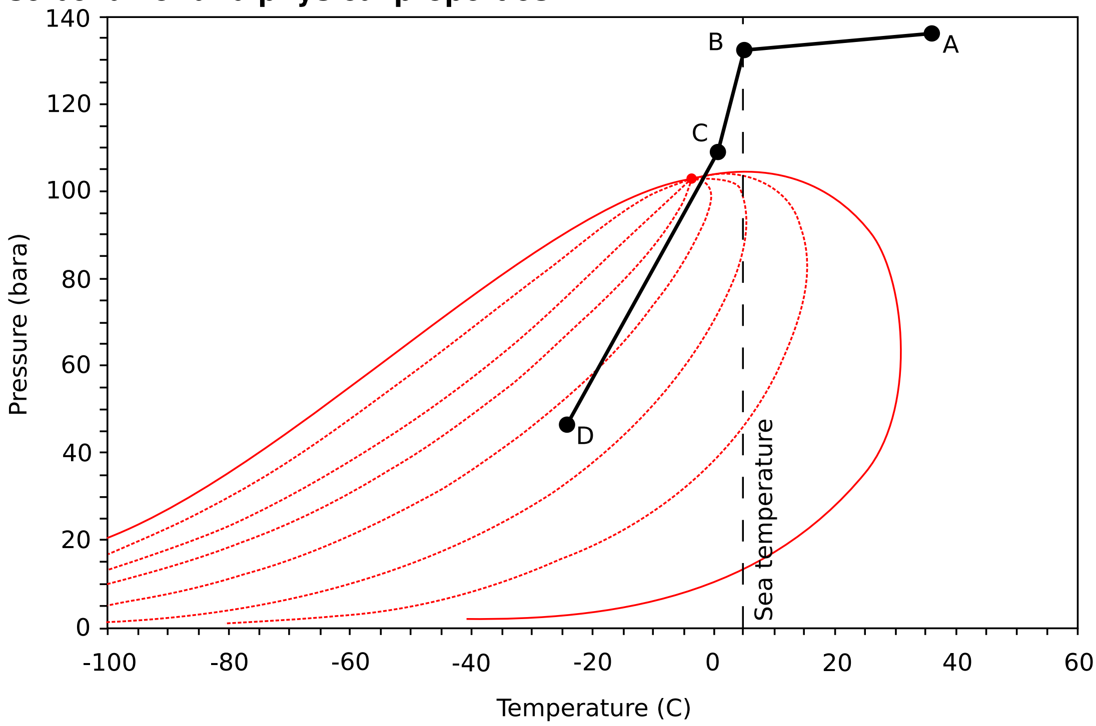

Figure 1: *The phase diagram for well-fluids produced offshore (point A) and the pressure-temperature path of the subsea pipeline (A→C) and initial treatment at (C→D) the processing plant.*

Consider a subsea well. The wellhead temperature and pressure are indicated by point A on the figure above. The gas processing terminal, which is some distance away, receives the fluids at the conditions indicated by point C.

a) Describe what might be occurring to cause the condition change A→B. Note that the relative pressure drop is small. **[5 marks]**

b) Describe what might be occurring between points B→C. In particular describe why the fluid is colder than the surrounding sea water. **[5 marks]**

c) Comment on the location of point C. Why is the subsea pipeline exit operated and designed at those conditions? Explain using key properties of the phase diagram. **[5 marks]**

d) Upon arrival to the processing plant, the process C→D is carried out. Explain why this is performed and how the process might be carried out, particularly if energy use is to be minimized. **[5 marks]**

[Question total: 20 marks]

Question 2

Fluid flow

a) For a centrifugal compressor describe the condition known as surge. **[4 marks]**

b) Describe the concept of equivalent length as used in piping system pressure drop calculations. **[2 marks]**

c) A polymer gel (density $\rho = 1000$ kg m^{-3} and viscosity $\mu = 0.01$ Pa s) injection system is sketched below which has an inner diameter of 0.1 m. A volumetric flow of 10,000 barrel day^{-1} is required. This is supplied to each well separately in sequence, so consider the two flow paths separately and at the full flowrate of 10,000 barrel day^{-1}. Calculate the pressure drops required to each well-head (B and C) assuming the pipe walls are smooth. Additional required information is available in Table 1 of the datasheet. **[10 marks]**

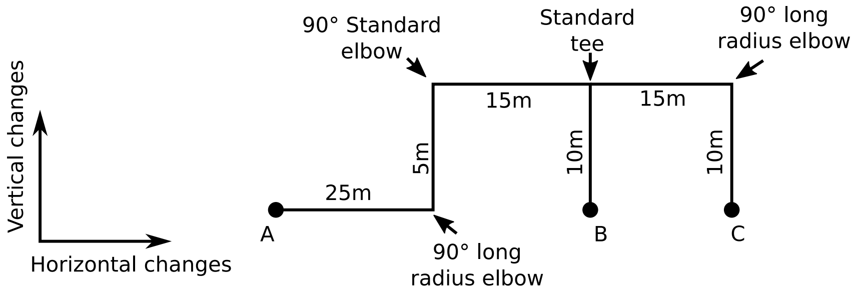

Figure 2: *The flow diagram for the water injection system, and the pipeline. Please note the difference between vertical height changes and horizontal distance changes.*

d) What equipment is required to maintain the required flowrate to each well? **[4 marks]**

[Question total: 20 marks]

Question 3

Multi-phase flow

a) Describe how gas introduced into the bottom of a well might increase the flow of oil. **[4 marks]**

b) Describe severe slugging and the underlying conditions which promote its appearance in a pipeline with a vertical riser system. **[6 marks]**

c) A downward sloping, 1000 m long pipeline with an internal diameter of 0.292 m joins a 100 m long vertical pipe (riser) of the same diameter. The pipeline contains oil, gas and water flowing at an average pressure of 20 bara. The flow rates are: Oil = 0.009 $m^3\ s^{-1}$, Water = 0.009 $m^3\ s^{-1}$, and Gas = to be determined.

   The oil and water densities are 800 and 1000 kg m^{-3} respectively. Determine the gas rate at which the system will start the cycle of severe slugging. **[10 marks]**

[Question total: 20 marks]

Question 4

Hydrates/dehydration

a) Describe hydrates and the main conditions necessary for hydrate formation. Why is hydrate formation a concern for transportation and process systems? **[4 marks]**

b) Hydrate formation can be calculated using K charts, an example of which is given in Fig. 3.

   Explain how these charts could be used to calculate the hydrate formation pressure at a given temperature for a known mixture of methane, ethane, propane and nitrogen. No chart is available for nitrogen.

   You should note the following relationship for the dewpoint of a hydrocarbon mixture.

$$\sum_{i=1}^{i=N_s} \left(\frac{y_i}{K_{VS,i}} \right) = 1$$

   where y_i is the mole fraction of species i and $K_{vs,i}$ is the equilibrium ratio between the gaseous/vapour fraction and the solid hydrate for each component. **[6 marks]**

c) To prevent hydrate formation a 2366 $Sm^3\ h^{-1}$ gas stream is to be dehydrated using a TEG contactor. The gas enters the dehydrator saturated at 80 bar and 30°C and lean TEG is available at 99% purity. Calculate the exit gas water concentration and the flowrate of TEG required assuming 0.04 m^3 per kg water removed is required. A safety factor of 10°C is also required.

   Equilibrium data are available in Fig. 4 and 5. **[8 marks]**

d) What TEG purity would be required to dehydrate the gas to 20 mg Sm^{-3}? **[2 marks]**

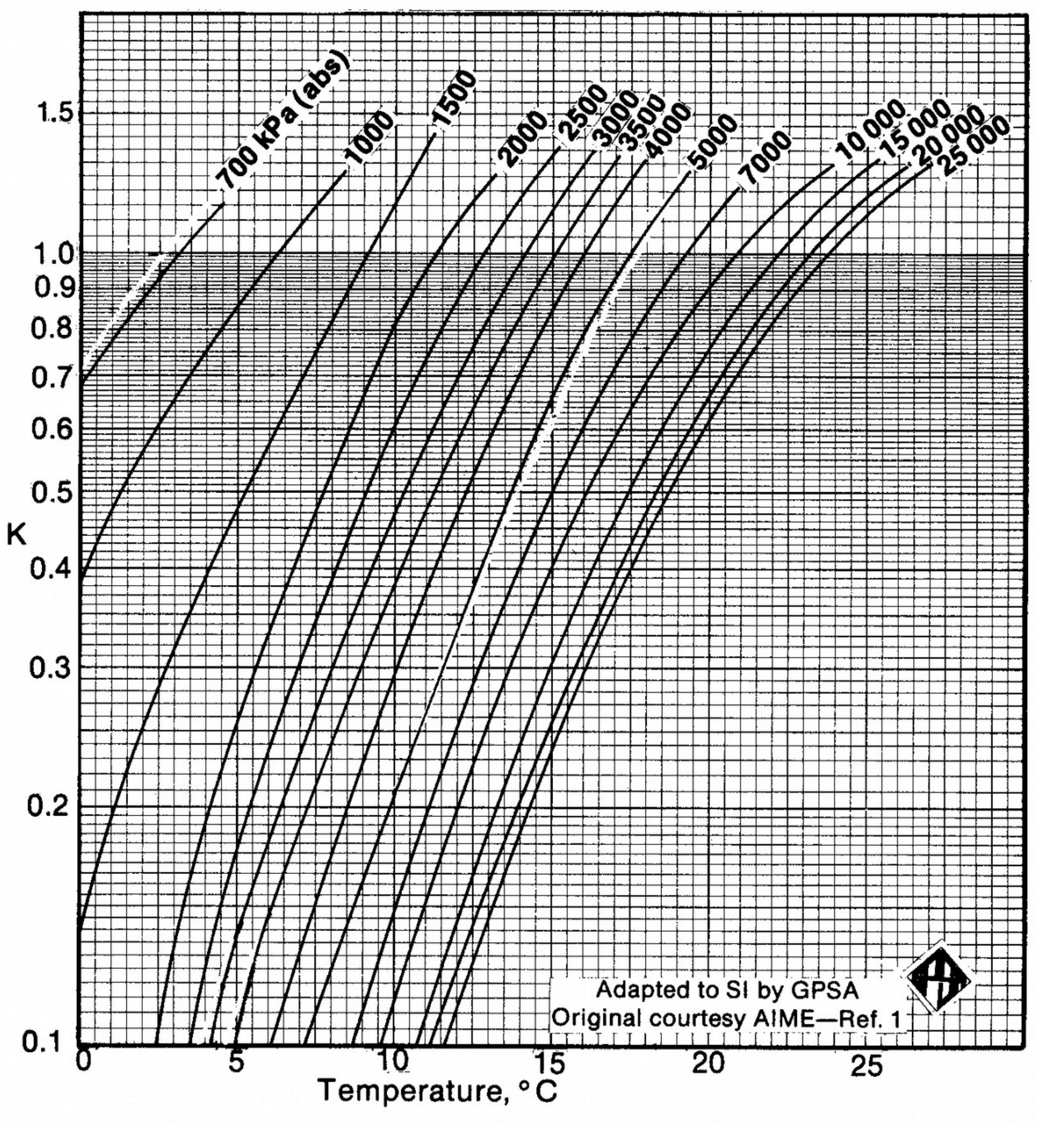

Figure 3: *Hydrate K-value chart for ethane.*

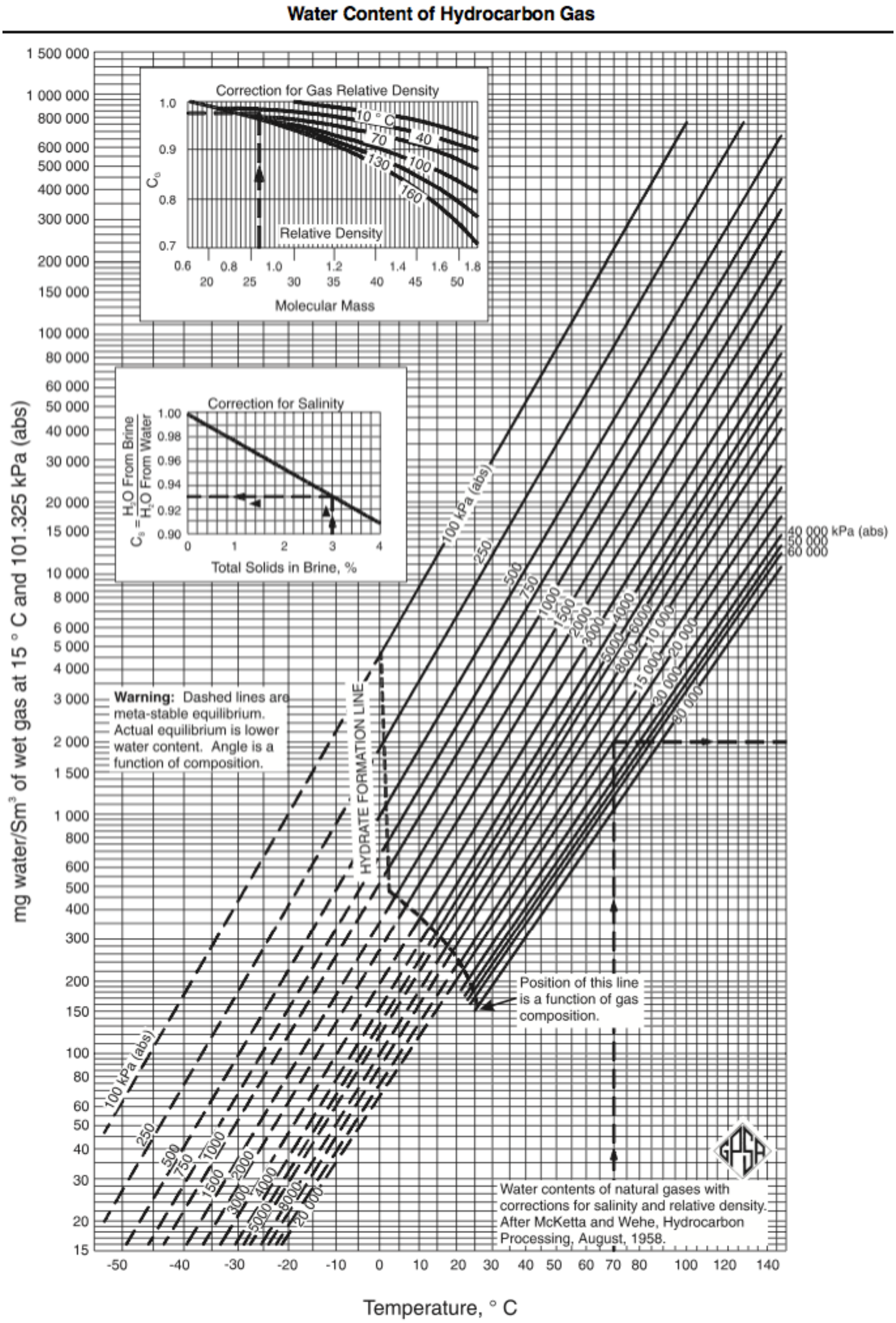

Figure 4: *Equilibrium chart for wet natural gas including corrections for water salinity and relative molecular weight/density.*

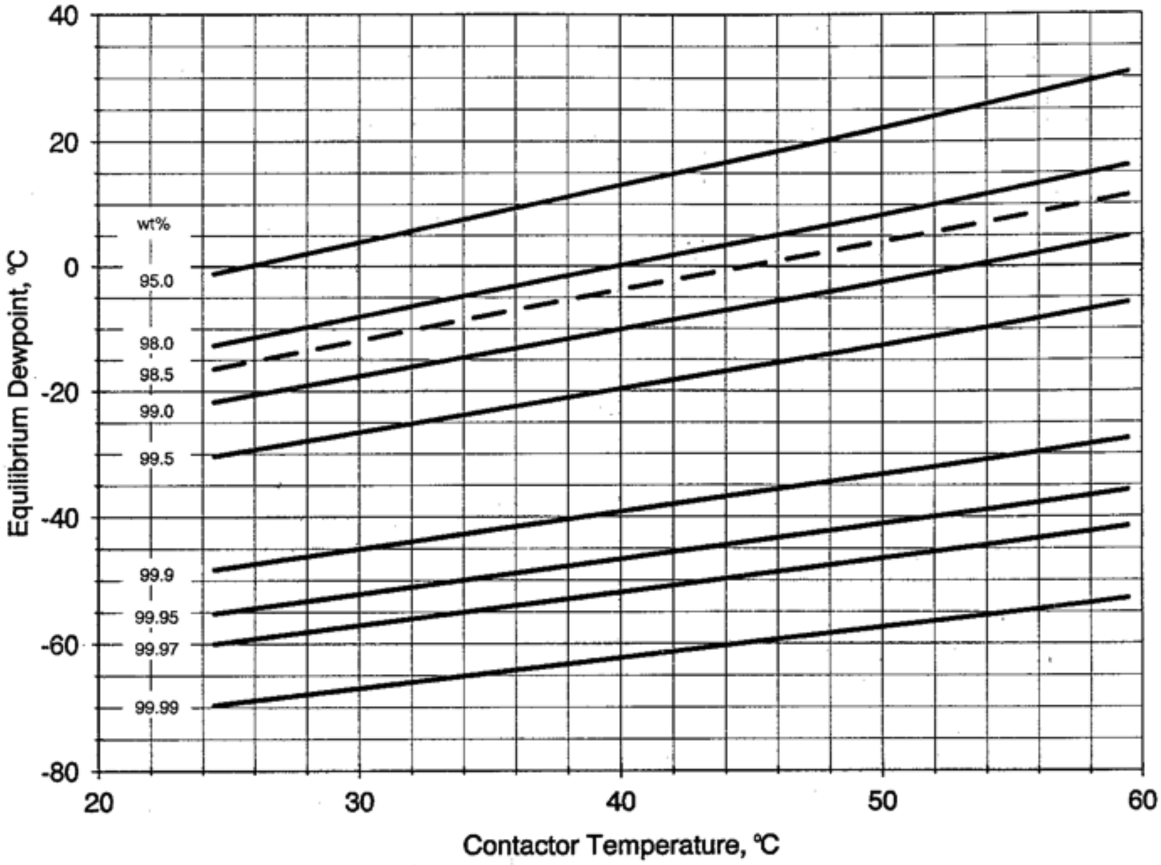

Figure 5: *Equilibrium correction chart for wet natural gas over TEG solutions.*

[Question total: 20 marks]

Question 5

Compression/expansion

a) A process gas is to be cooled from 20°C to -35°C using a refrigeration plant. The refrigerant is propane. Using the attached Mollier chart (see Fig. 6) for propane estimate the compressor energy savings between a one and a two stage refrigeration system. Assume air is available at 25°C for condensation. State any other assumptions. Enclose your Mollier chart including your student number with the returned exam booklet. **[14 marks]**

b) State and explain six factors in deciding whether to use a one or two stage refrigeration system. **[6 marks]**

[Question total: 20 marks]

If you use this graph, you must attach it to your exam booklet using the provided tag.
Student ID:

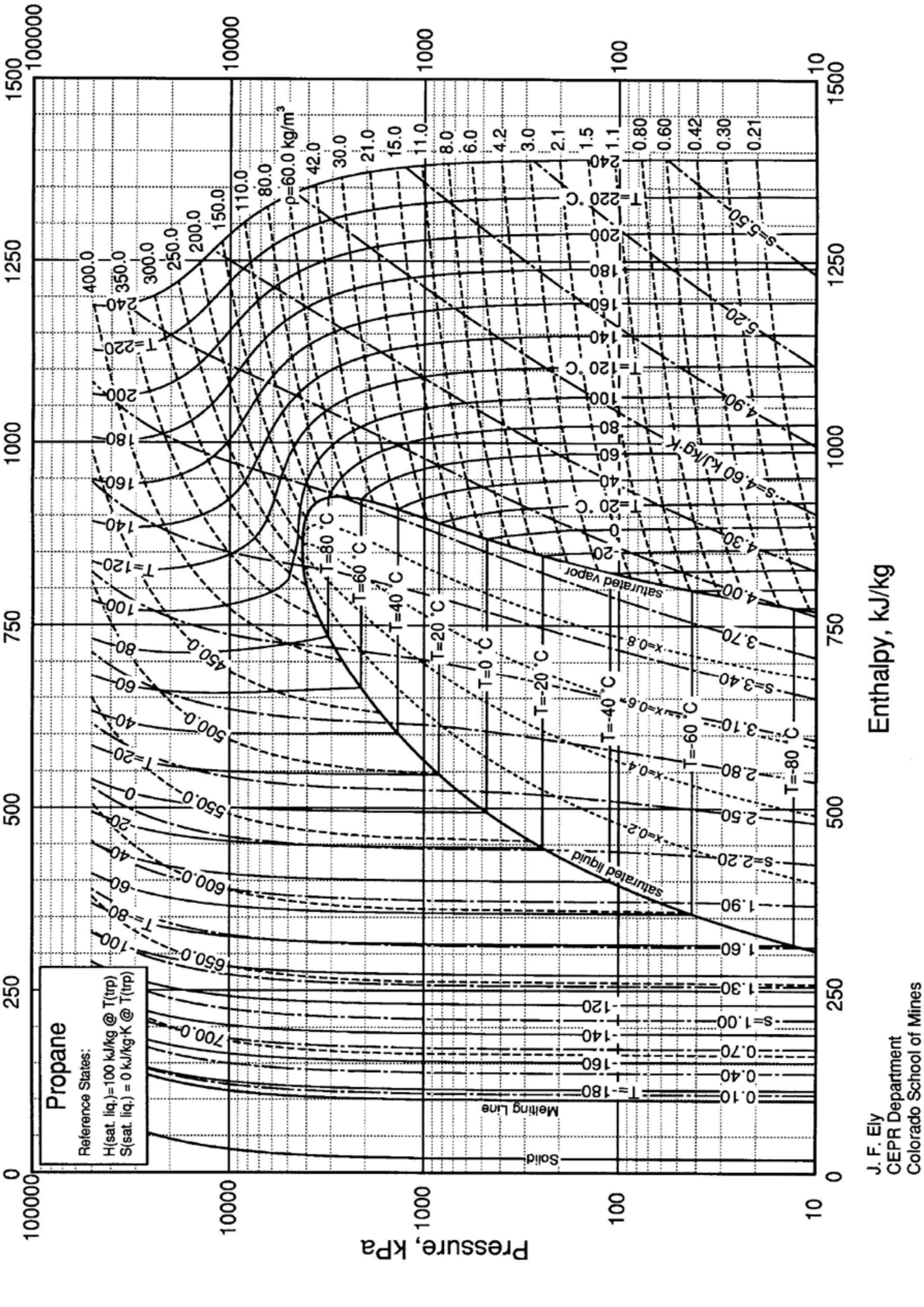

Figure 6: *A Mollier chart for propane.*

END OF PAPER

Unit conversions

$$1 \text{ US barrel} = 42 \text{ US gallons} = 0.159 \text{ m}^3$$
$$1 \text{ ft} = 12 \text{ in} = 0.3048 \text{ m}$$
$$1 \text{ lb} = 0.453592 \text{ kg}$$
$$^\circ\text{F} = (^\circ\text{C} \times 9/5) + 32$$
$$^\circ\text{C} = (^\circ\text{F} - 32)\,5/9$$

Physical constants/properties

Air molecular weight = 29 g mol^{-1}

Darcy's equation

$$\Delta p = \frac{\rho\, f\, L\, v^2}{2\, D}$$

Blasius correlation (turbulent flow)

$$f = 0.316\,\mathrm{Re}^{-0.25}$$

Pipe fitting	Equiv. length (L/D)
90° standard elbow	30
45° standard elbow	16
90° long elbow	20
90° street elbow	50
45° street elbow	26
Square corner elbow	57
Standard tee (flow through run)	20
Standard tee (flow through branch)	60
Close pattern return bend	50

Table 1: *A list of equivalent lengths for single phase fluid flow calculations.*