National Exams December 2012

98-Pet-A7, Secondary and Enhanced Recovery

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM. Any non-communicating calculator is permitted.
3. FOUR (4) questions constitute a complete exam paper. The first four questions as they appear in the answer book will be marked.

Problem 1 (30 points)

The oil and water relative permeability curves for a particular line drive waterflood are given as follows:

$$k_{rw} = k_{rw}^0[(S_w - S_{wc})/(1 - S_{wc} - S_{or})]^2$$
$$k_{ro} = k_{ro}^0[(S_o - S_{or})/(1 - S_{wc} - S_{or})]^2,$$

where k_{rw} : Water relative permeability
k_{ro} : Oil relative permeability
S_w : Water saturation
S_o : Oil saturation
$k_{rw}^0 = 0.20$
$k_{ro}^0 = 0.80$
$S_{wc} = 0.20$
$S_{or} = 0.30.$

Other pertinent data are given below.

Distance between the wells: 2700 ft
Cross sectional area for the line drive: 3000 ft^2
Porosity: 0.25
Initial S_w: 0.20
Oil viscosity: 5.0 cp
Water viscosity: 1.0 cp
Constant water injection rate: 200 STB/Day

a. (5 points) Calculate and plot the fractional flow curves for the water phase without gravity and capillarity. Use the attached graph sheet.

b. (5 points) Perform the Welge tangent-line construction and indicate the correct saturation path from the initial to the injection saturation.

c. (10 points) Calculate the water breakthrough time in days.

d. (10 points) Plot the expected 1-D water saturation profile at 0.25 pore-volumes of water injected. The plot should have the water saturation on the y axis and the distance from the injector on the x axis.

Problem 2 (20 points)

Refer to Figure 1 and answer the following questions:

a. (5 points) A mixture containing 80 mol% CO_2 is separated into liquid and vapor at 150°F and 975 psia. What is the critical pressure of the vapor phase? What is the critical temperature of the liquid phase?

b. (5 points) A mixture has a critical temperature at 110°F. What is the bubble point pressure of that mixture at 80°F?

c. (5 points) What is the state of a mixture containing 50 mol% CO_2 at 240°F and 800 psia?

d. (5 points) One mole of a mixture containing 75 mol% CO_2 in C_5 is placed in a PVT cell at 103°F and 700 psia. What are the compositions of equilibrium liquid and vapor and how many moles of the liquid phase are present?

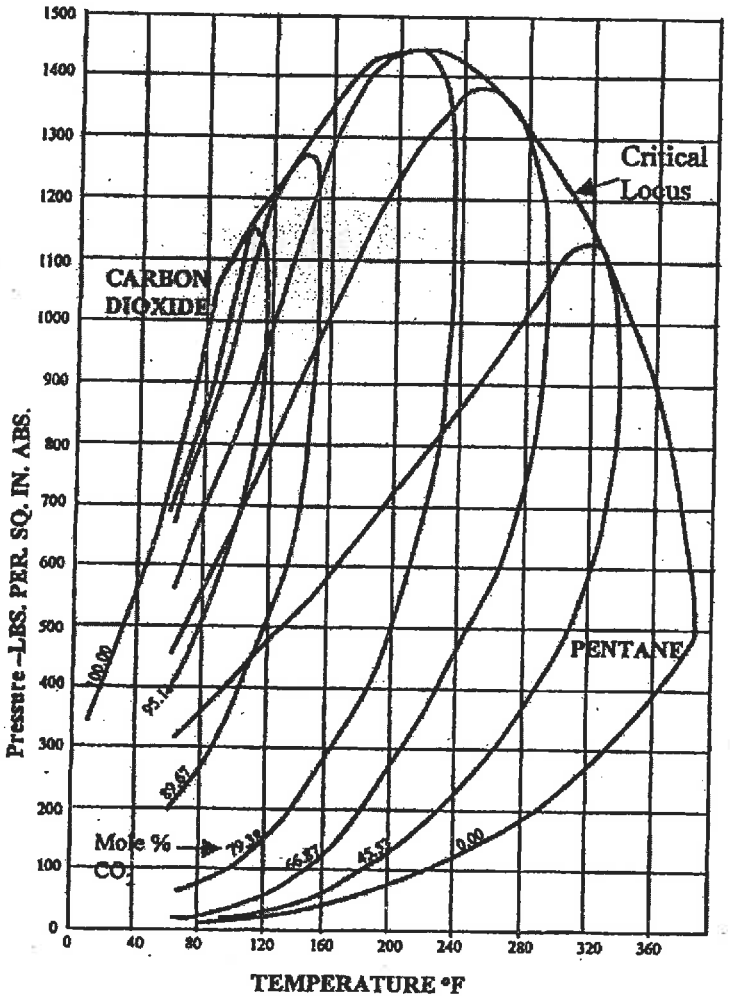


Figure 1. Pressure-temperature diagram for binary mixtures of CO_2 and Pentane.

Problem 3 (25 points)

Displacement of oil in steamflooding involves a number of different mechanisms. Oil is contacted first by cold water, then by hot water, and finally by steam. Figure 2 schematically shows saturation and temperature profiles for a one-dimensional steamflood. As shown in Figure 2, propagation of heat fronts is much slower than that of cold water fronts in steamflooding.

a. (10 points) Please explain the most fundamental reason for the slow propagation of heat fronts in a steamflood.

b. (15 points) The endpoint mobility ratio is sometimes used as a correlating factor for volumetric sweep efficiency of displacement processes. The general definition of mobility ratio, however, is the pressure gradient ahead of the displacement front divided by the pressure gradient behind the front. Please calculate the general mobility ratio for a heat front in a steamflood, assuming the front is piston-like. Is the displacement front in this steamflood stable?
Pertinent data:
Density of steam: 10^{-3} g/cm^3
Density of oil: 0.8 g/cm^3
Viscosity of steam: 10^{-6} Pa-s
Viscosity of oil: 2×10^{-3} Pa-s
Endpoint relative permeability for steam: 0.35
Endpoint relative permeability for oil: 1.0

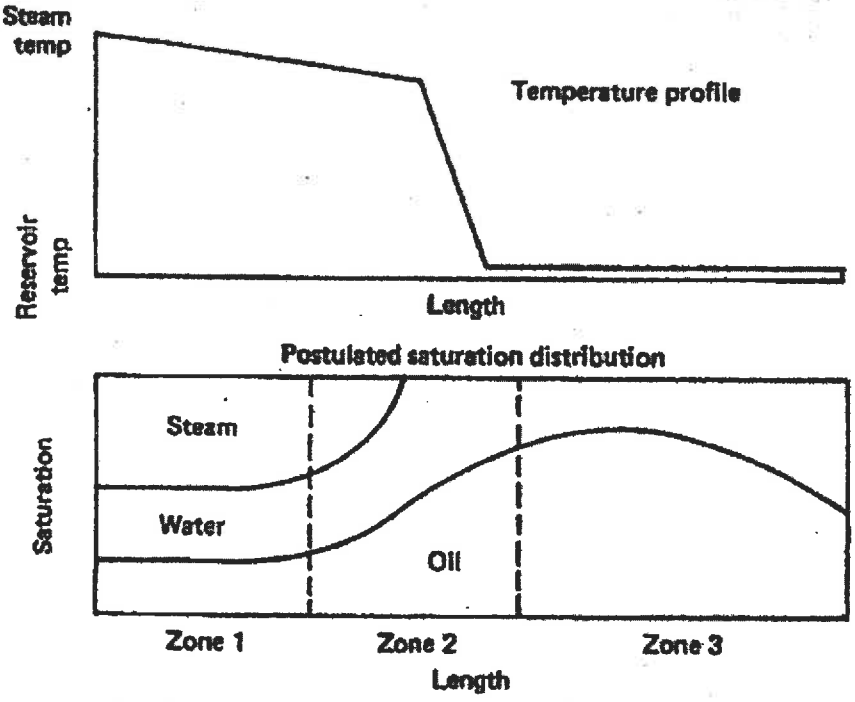


Figure 2. Schematic of saturation and temperature profiles in a steamflood (Boberg 1965).

Problem 4 (25 points)

Please answer the true and false questions given below. Briefly explain reasons for each of your answers.

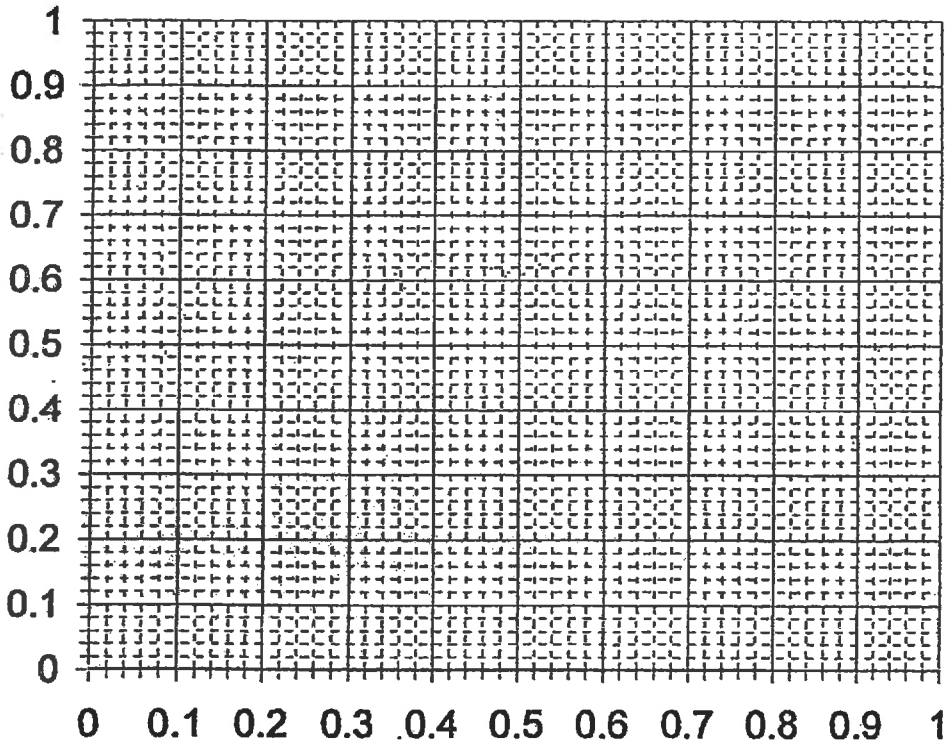
a. (5 points) The ultimate displacement efficiency in a waterflood is 100%: True or false? Why?

b. (5 points) The ultimate displacement efficiency of a miscible gasflood is 100%: True or false? Why?

c. (5 points) The effect of dispersion on oil recovery from a miscible gas flood in the lab is likely the same as in the field: True or false? Why?

d. (5 points) In general, thermal methods are more efficient for deeper reservoirs: True or false? Why?

e. (5 points) In a linear hot-water flood, the cold-water breakthrough time depends on the temperature of injected hot-water: True or false? Why?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