A

University of Stavanger

DATE:19th of December, 2017

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET-500 PVT of Reservoirs and Fluids

TIME: 4 hours

AID: No printed or written means allowed. Definite basic calculator allowed.

THE EXAM CONSISTS OF 2 PARTS ON 7 PAGES AND 4 ADDITIVES.
Part 1 is given equal weight as Part 2.

REMARKS: All answers in English. Answers on carbon paper.

PART 1: Reservoir Geology (50% Exam)

Part 1a: 12 questions (25% Exam)

1. **Explain the volumetric formula for gas field reserve calculation (surface conditions) and how to estimate the parameters involved.**

2. **Explain how to estimate hydrocarbon reserves (surface conditions) in shale reservoirs. Describe the parameters involved.**

3. **According to Reading and Richards, submarine fans can be divided in 3 systems, what are they and make a brief description of each of them. Which is most likely to characterize North Sea Reservoirs > 80% Net-to-Gross sand?**

4. **What is Basin Modelling? And what are two main purposes of this kind of modelling?**

5. **The precipitation rate of Quartz cementation in sandstone reservoirs is an exponential function of what subsurface parameter and linear function to what another parameter?**

6. **Which are the 4-main petroleum sedimentary basin types, which has the 75% of the world's conventional oil reserves, and give two reasons why?** → siste

7. **For depositional systems, according to "Walther's Law", what generates vertical sequences of sediments?**

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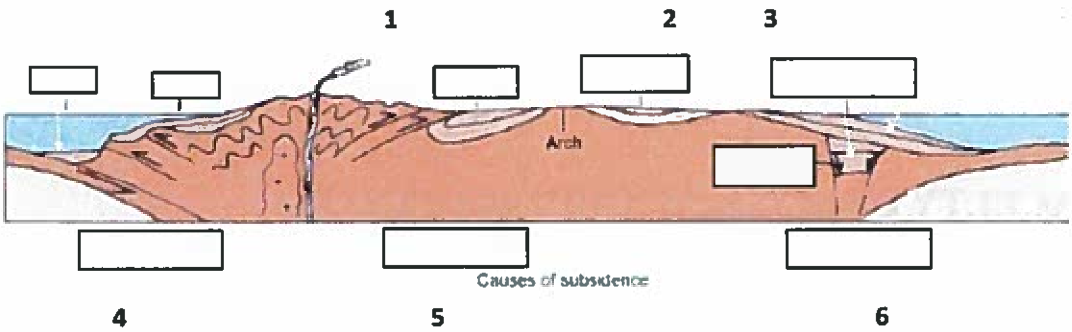
8. From the tectonic illustration below, number and fill in the various basin types (1-3) as well as the mayor causes of subsidence (4-6).



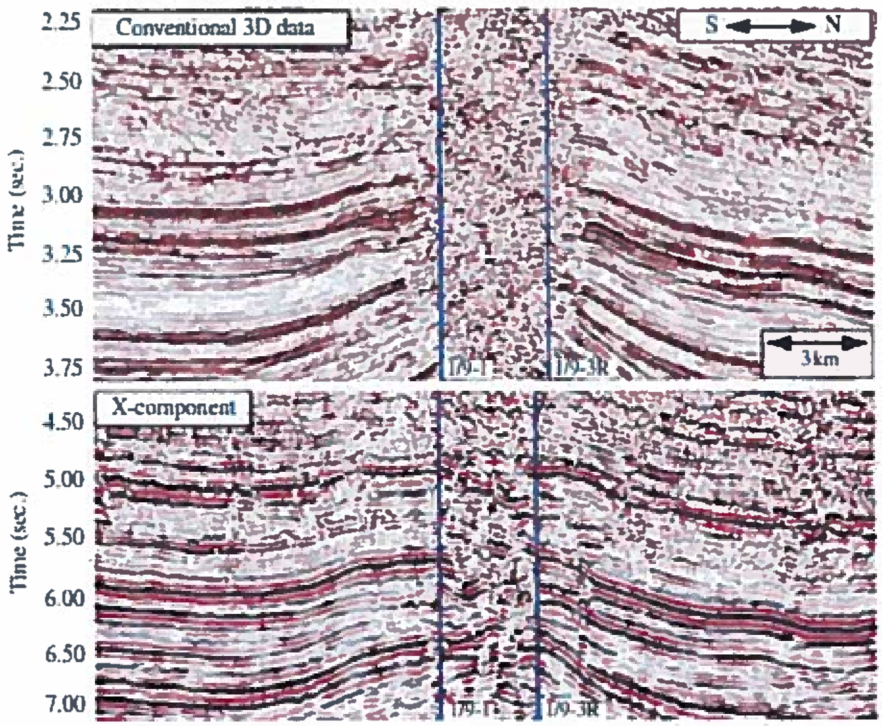
9. **GEOPHYSICS/SEISMIC INTERPRETATION RESERVOIRS & FLUIDS**

a) **The figure below shows two seismic datasets acquired at approximately the same location, i.e., for the same part of the subsurface. Describe as fully as you can these two sections and the several differences between them. Your answer should include, but not be limited to:**

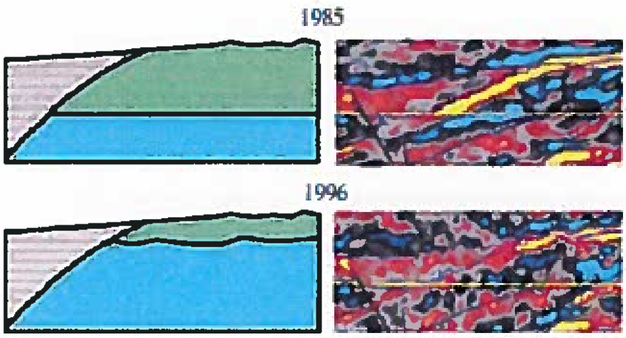
i. **The details of what kind of dataset each one is (including what is meant by the annotations on the figures);**

ii. **What the zone in the middle (demarcated by the vertical blue lines) represents, and why it looks better on one section than on the other;**

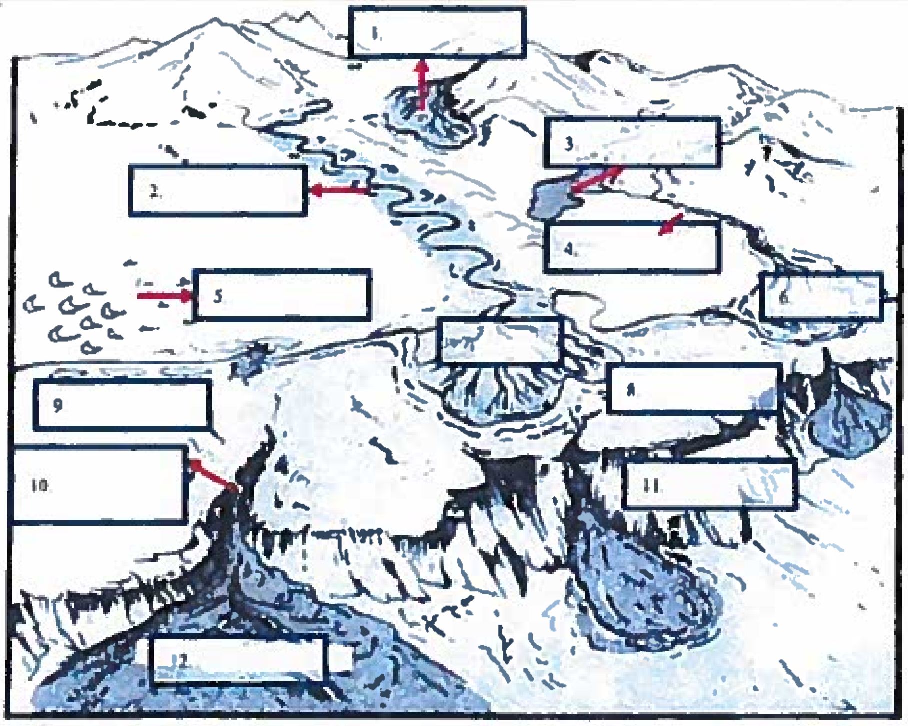
iii. **An explanation of the time-scale values on the left.**



b) In a similar way, give your own account of what the figure below shows after 11 years of reservoir production history.



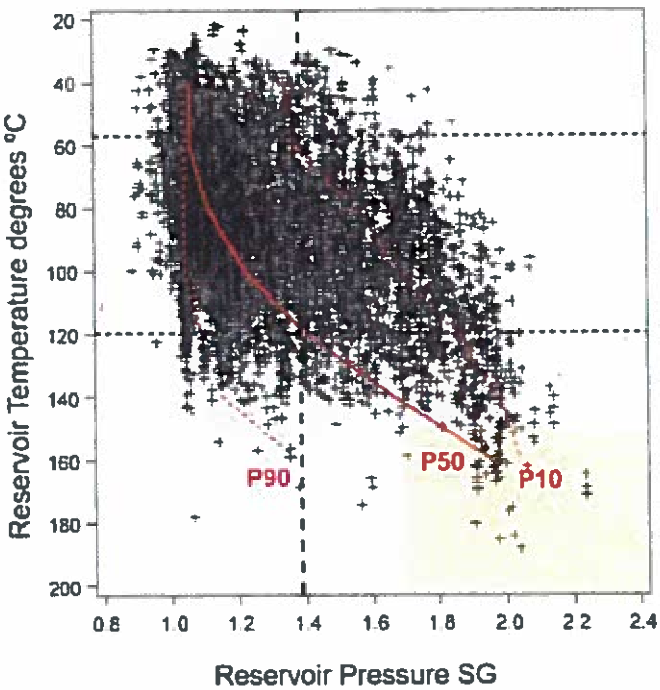
10. Complete the following Depositional Environment diagram:



11. Compare the following for Carbonates vs Sandstones:

	Carbonates	Sandstones
Heterogeneity		
Amount of primary porosity in sediments		
Amount of ultimate porosity in sediments		
Permeability-Porosity Interrelation		
Influence of Diagenesis		
Percentage of Reservoirs in the world		
Percentage of HC reserves in the world		

12. The figure below shows the relationship of pressure and temperature for Gulf of Mexico reservoirs. The pressure probabilities for P90, P50 and P10, as a function of temperature are shown as red lines. Divide the diagram into the following areas: NPNT, NPHT, NPLT, HPNT, HPLT, HPHT, where N= Normal, P= Pressure, T= Temperature, H= High, L= Low. Name 2 geological processes which may be responsible for the occurrence of HPHT, and what are pressure and temperature boundaries for HPHT drilling used in the petroleum industry?



500
1·2
2

13. BONUS QUESTION (correct answer will credit an incorrect answer in 1-12).
What is it more expensive: a litre of water, a litre of Brent crude oil or a litre of gasoline (bensin) in Norway?
Assume the price of a 0.33 litres water bottle is 25 Kroner [Kr]?
HINT: State the price of Brent oil barrel, litre of Gasoline and USD/NOK exchange rate dated 18.12.2017, cite your sources.

Part 1b (25% of exam):

A. You have been tasked to estimate the volumes of oil/gas of 3 Norwegian Continental Shelf (NCS) prospects in term of:
   a) In-place resources of oil/gas in cubic meters at **reservoir conditions.**
   b) Recoverable reserves of oil/gas in cubic meter at **surface conditions.**

You must consider just the oil case for the oil reservoir, just the gas case for the gas reservoir, and both cases for the unknow reservoir. Your employer is mostly interested in high value of **Oil reserves,** and also expects your recommendation of which prospect to prioritize for drilling.
Your subsurface team has provided you with the following information:

Prospect	Water Depth	Dimensions	Depth Crest	Depth Spill Point
1	850	20 x 40 km	2690	3010
2	360	12 x 20 km	4600	5400
3	235	10 x 15 km	1600	1700

Prospect	Reservoir T °C	Geological Age	Depositional Environment
1	100	Paleocene	Deep Marine
2	170	Jurassic	Shallow Marine
3	75	Jurassic	Shallow Marine

Additional information:
Prospect 1 has a strong flat seismic feature neat the mapped spill.
Prospect 2 has no data available.
Prospect 3 has a very weak flat seismic feature near the spill point.
Tasks:

- ✓ State the reservoir analogue.
- ✓ Do the calculation clearly.
- ✓ State your further plan of development (what to do, prioritization, proposed production scenarios).

B. A Norwegian Arctic shelf prospect has been identified at 1.5 Km depth. Pressure of the reservoir is estimated to be 150 bar (hydrostatic gradient). Basin modelling indicates that the prospect was charged fill to spill during maximum burial at 3 Km depth, with a reservoir pressure of 300 bar. Estimates are that the reservoir initially contains 100 Million m^3 of oil and 100 million m^3 of gas, at reservoir conditions during maximum burial. Assuming that the prospect area has undergone 1.5 Km of uplift and erosion, what would the estimated volumes of oil and gas in the uplifted reservoir be today assuming that the trap volume and relative spill point are unchanged? Briefly Explain.

Part 2, PVT of Fluids 8 Questions (50% *of exam)*:

A representative hydrocarbon fluid sample are taken from a reservoir.

Based on the measured compositional data of the reservoir fluid, a constant mass expansion (CME) and a separator test are modelled, Table 1 and Table 2 respectively.

Table 1 CME data at T_{res} :

Pressure Bar	Rel Vol V/V_b	Compressibility 1/Bar	Y-factor
500	0.9634	1.134 E-04	
450	0.9693	1.240 E-04	
400	0.9759	1.364 E-04	
350	0.9832	1.510 E-04	
300	0.9914	1.686 E-04	
253.3	1.0000	1.884 E-04	
250	1.0033		4.02
200	1.0725		3.68
150	1.2087		3.30
100	1.5271		2.91
50	2.6158		2.54

Table 2 Separator test:

Pressure Bara	Temp, °C	GOR Sm^3/Sm^3	Gravity Air =1	Oil Density g/cm^3	FVF* m^3/Sm^3
253.3	80.0			0.732	1.340
100.0	60.0	73.7	0.682	0.796	1.155
30.0	40.0	31.1	0.710	0.834	1.070
1.0	15.0	21.3	1.048	0.865	1.000

*FVF = formation volume factor

The following reservoir data are given:

Initial pressure:	P_i = 450 bar
Reservoir temperature:	T_{res} =80 °C
Bulk reservoir volume:	$V_B = 10^6 m^3$
Reservoir Porosity:	$\emptyset$ = 0.25
Residual water saturation:	S_{wi} = 0.2.

a.

Describe shortly different fluid sample techniques that could be used to obtain a representative sample of this reservoir fluid.
Is there any of these method you would recommend and why?

b.

Describe how the chemical composition analyses is performed experimentally on a representative reservoir fluid sample.

c.

What is the value of P_b at T_{res}? Verify that the value of P_b is determined correctly.

d.

Determine:

1. Initial oil formation factor, $(B_o)_i$
2. Initial oil in place and initial gas in place, IOIP and IGIP, as Sm^3.

e.

Calculate the recovery of STO (Sm^3) and gas (Sm^3) during a pressure depletion from P_i to P_b. It is supposed that the HCPV is constant during the production.

f.

Show that the average molecular weight of produced gas is given by: $M_g = 21.7$.

g.

According to the simulated separator test, it is seen that $(\rho_o)_b = 0.732\ g/cm^3 = 732\ kg/m^3$.
Calculate $(\rho_o)_b$ by using the added empirical correlations and actual values from the separator test.
Compare the values and give comments.

h.

Suppose that the reservoir fluid is produced by a pressure depletion from P_i to P_a=100 bar. Illustrate the following relations:

1. $GOR = f(P_{res})$
2. $Bo = f(P_{res})$
3. $\rho_o = f(P_{res})$
4. $\mu_o = f(P_{res})$
5. $\mu_g = f(P_{res})$

Addition 1.

Important conversion factors, formula/correlations.

Temperature:

°K = 273.15 + °C
°F = 1.8 x °C + 32
°R =°F + 459.69

Pressure:

1atm = 1013.250 mBar = 1.013250 bar = 101.3250 kPa = 0.1013250 MPa = 14.69595 psia
psia = 14.69595 + psig
1 atm = 760.002 mmHg at 0 °C

Density:

1 g/cm^3 = 62.43 lb/ft^3 = 350.54 lb/bbl
1 lb/ft^3 = 16.0185 kg/m^3
ρ_w = 0.999015 g/cm^3 (60 °F, 1 atm)
ρ_w = 0.9991 g/cm^3 (15 °C, 1 atm)

Specific density:

For liquids: Determined relative to water at sc.
For gases: Determined relative to air at sc.

$$\gamma_o = \frac{\rho_o}{\rho_w} = \frac{141.5}{131.5 + {}^oAPI}$$

$$ {}^oAPI = \frac{141.5}{\gamma_o} - 131.5$$

$$\gamma_g = \frac{M_g}{M_{air}} = \frac{M_g}{28.96}$$

Cragoe's formula (empirical formula giving molecular weight of hydrocarbons):

$$M_o = \frac{6084}{{}^oAPI - 5.9}$$

Volume:

1 bbl = 5.615 ft^3 = 0.15898 m^3
1 ft^3 = 0.0283 m^3
1 US Gallon = 3.785 litre
1 Imp. Gallon = 4.546 litre
Molar volume of gas at standard conditions:
V_m = 379.51 SCF/lb mole (60 °F and 14.69595 psia)
V_m = 23644.7 cm^3/g mole = 23.6447 m^3/kg mole (15 °C and 101.3250 kPa)

Air:

Z_{air} = 0.9959 (60 °F, 14.69595 psia)
M_{air} = 28.96

Gas constant:

R = 10.732 (psia, ft^3, °R, lb mole)
R = 0.082054 (atm, litre, °K, g mole)
R = 8.3145 (kPa, m^3, °K, kg mole)

Addition 2.

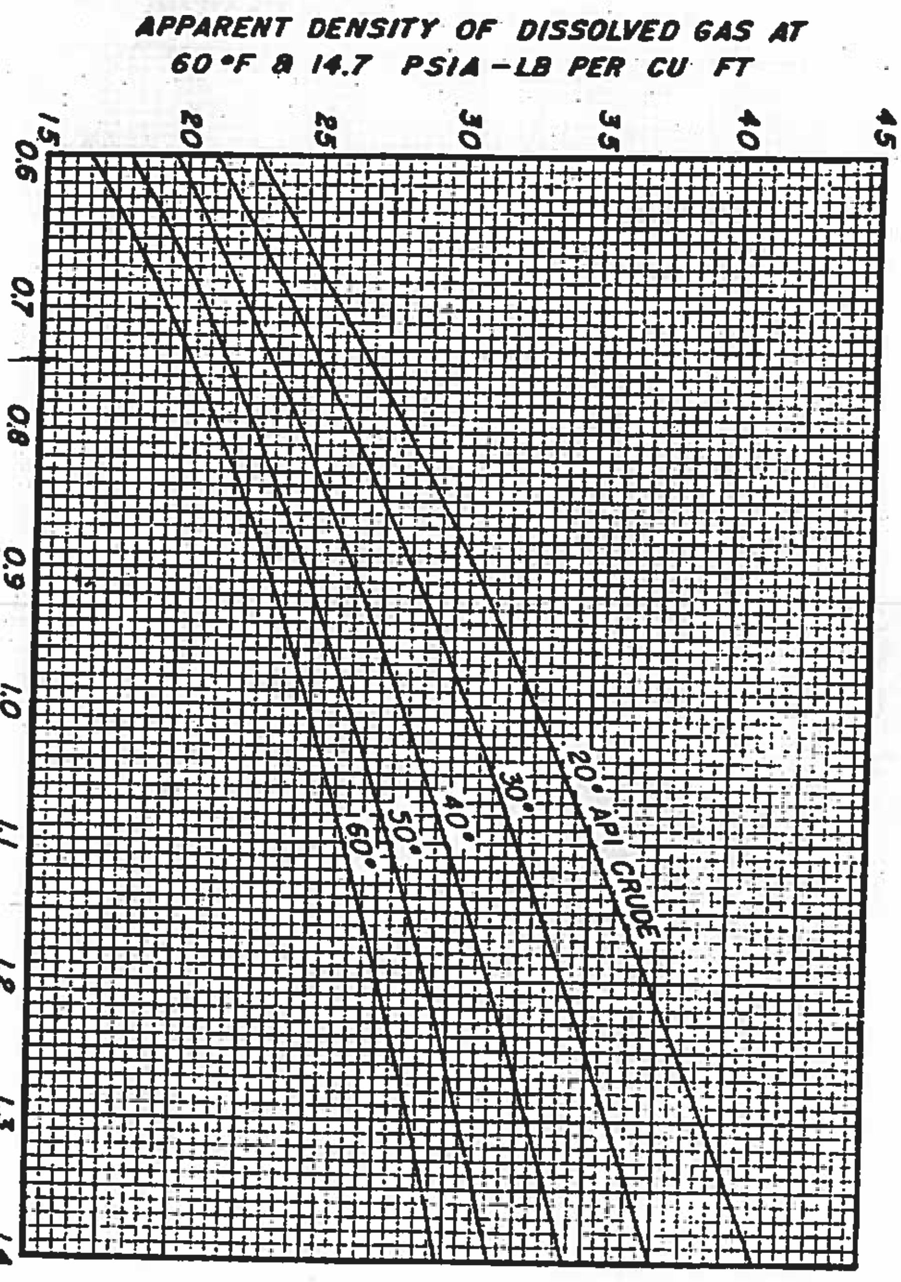


Figure 26—Apparent Liquid Densities of Natural Gases (After Katz, API Drilling and Production Practice, 1942)

Addition 3.

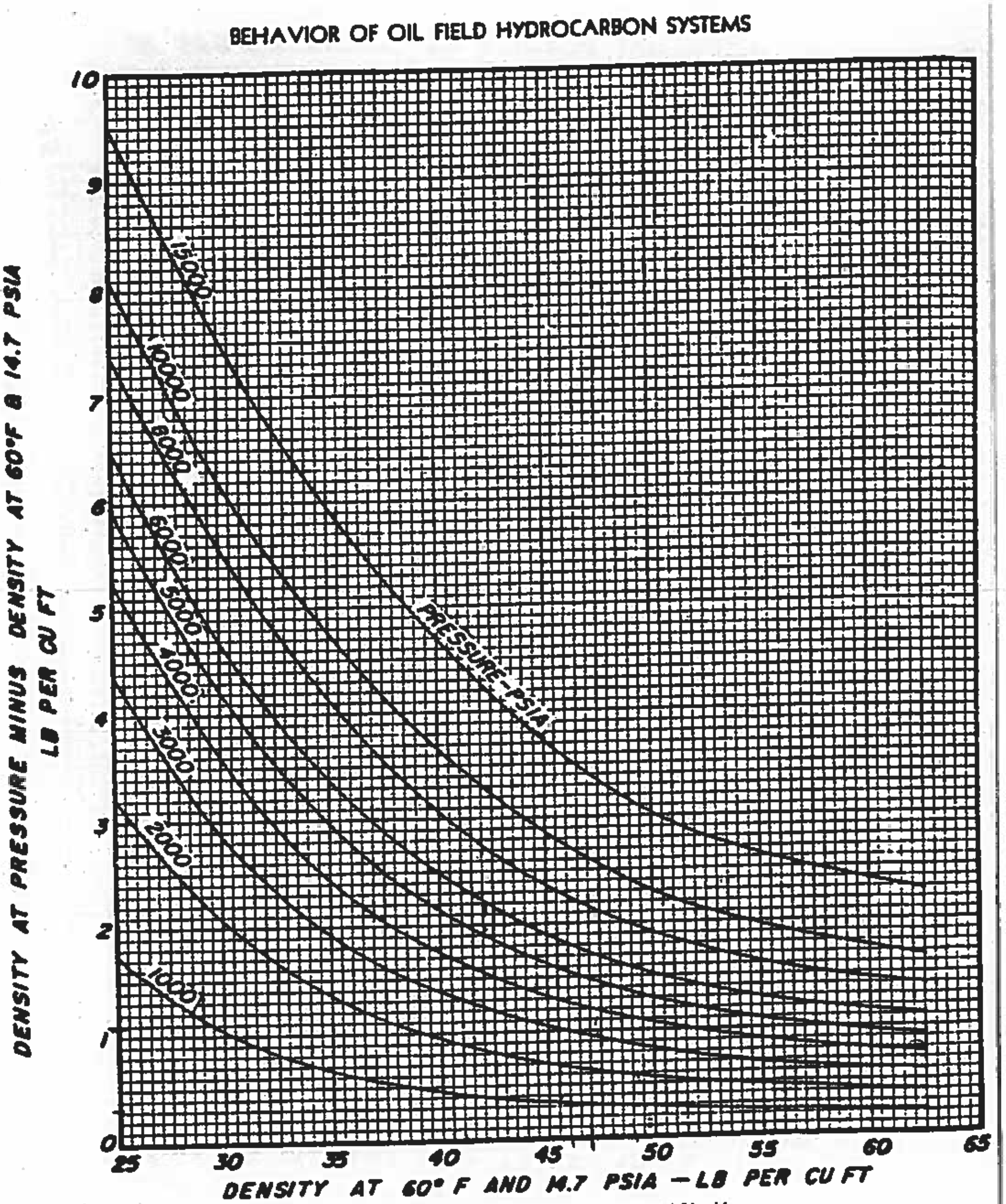


Figure 24—Density Correction for Compressibility of Liquids

Addition 4.

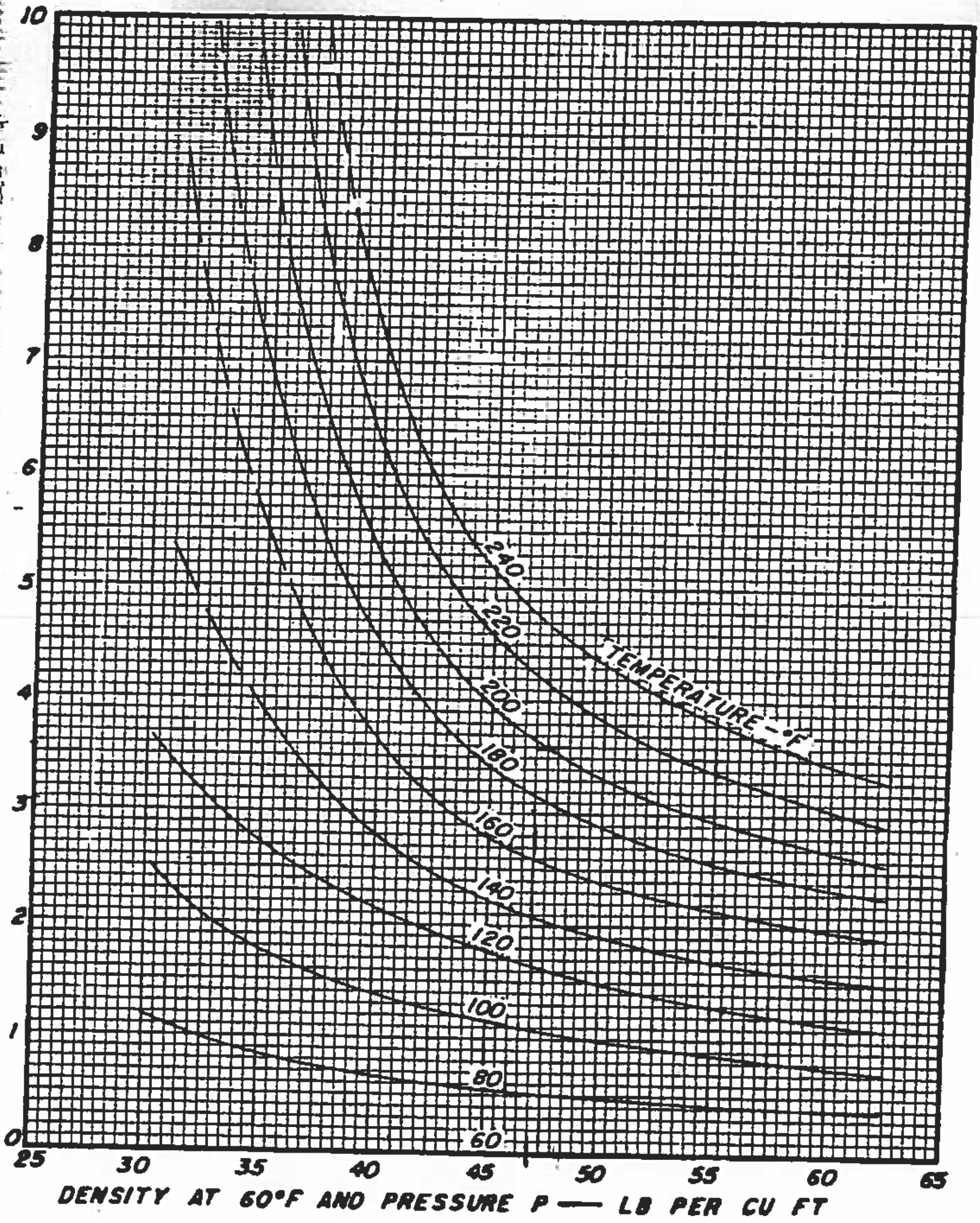


Figure 26—Density Correction for Thermal Expansion of Liquids