ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2012 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

04 – CHEM A3 MASS TRANSFER OPERATIONS

Question # 1 Distillation **(16 points)**

Your colleague and you were given a project to design a distillation column to separate an equimolar mixture of benzene with toluene at 1 atm at rate of 100 kmol/h. Your colleague had to leave unexpectedly for Calgary leaving you the results he obtained in the form of a graph that is attached.

Based on the analysis of your colleague's results you should determine different parameters characterizing the distillation:

a) x_F = ; x_D = ; x_B = ;

b) D = ; B = ;

c) V = ; $\overline{V}$ = ; ; L = ; $\overline{L}$ = ;

d) N (without reboiler) = ; N_{min} (without reboiler) = ;

e) R_{min} = ; R/R_{min} = ; q = ;

f) Thermal characteristics of the feed. = ;

Question # 2 Distillation **(16 points)**

To verify your colleague's results shown in the figure of question 1, you should recalculate the problem by using the method FUG (Fenske-Underwood-Gilliland) and determine:

a) N_{min} = ;

b) R_{min} = ;

c) N for the case R = R_{min} x 2.56

Question # 3 Equilibrium **(10 points)**

In the petrochemical plant a mixture of 50 kmol/h propane and 50 kmol/h ethane is fed by a pipe. The pipe is kept at 56^{o}C and pressure of 5 atm.

You should calculate the maximum flow-rate of pentane in kmol/h that has to be added to the mixture propane-ethane without causing a condensation in the pipe.

Note: the chart with K_i is attached at the end of the exam.

Question # 4 Desorption **(16 points)**

Chlorinated compounds such as trichloroethylene have the tendency to dissolve in water. One of the means to remove them is to treat the contaminated water with a flow of air in a desorption column.

Desorption column to treat 18 m^3/h of water containing 200 molar ppm trichloroethylene has to be designed. By the designed column operating at 1.2 atm 90% of trichloroethylene has to be removed from water. Henry's constant for the operating conditions is H = 643 atm.

> You should calculate by using group method (Kremser) number of desorption column stages for the case of air flow rate equal to 2.22x minimum flow rate.

Question # 5 Humidity **(15 points)**

Circulation of humid air in vegetable cellars very often during the summer causes water condensation.

The humid air having a dry-bulb temperature of 30^{o}C and wet-bulb temperature of 21^{o}C is fed to the cellar where the temperature is kept at 5^{o}C.

For a flow rate 5 m^3/min calculate the amount of water condensing during 24 h.

Note: the psychrometric chart is attached at the end of the exam.

Question # 6 Extraction liquid-liquid **(12 points)**

For plane de-icing during winter aqueous solutions of ethylene glycol are often used. Regeneration of the diluted solutions can be achieved by extraction using furfural.

For regeneration of 1 t of solution containing 45mass% ethylene glycol, determine by using the attached ternary diagram:

a) the amount of furfural needed to obtain by a single extraction a raffinate containing only 9 mass% ethylene glycol;

b) The amounts and compositions of the two phases resulting from extraction.

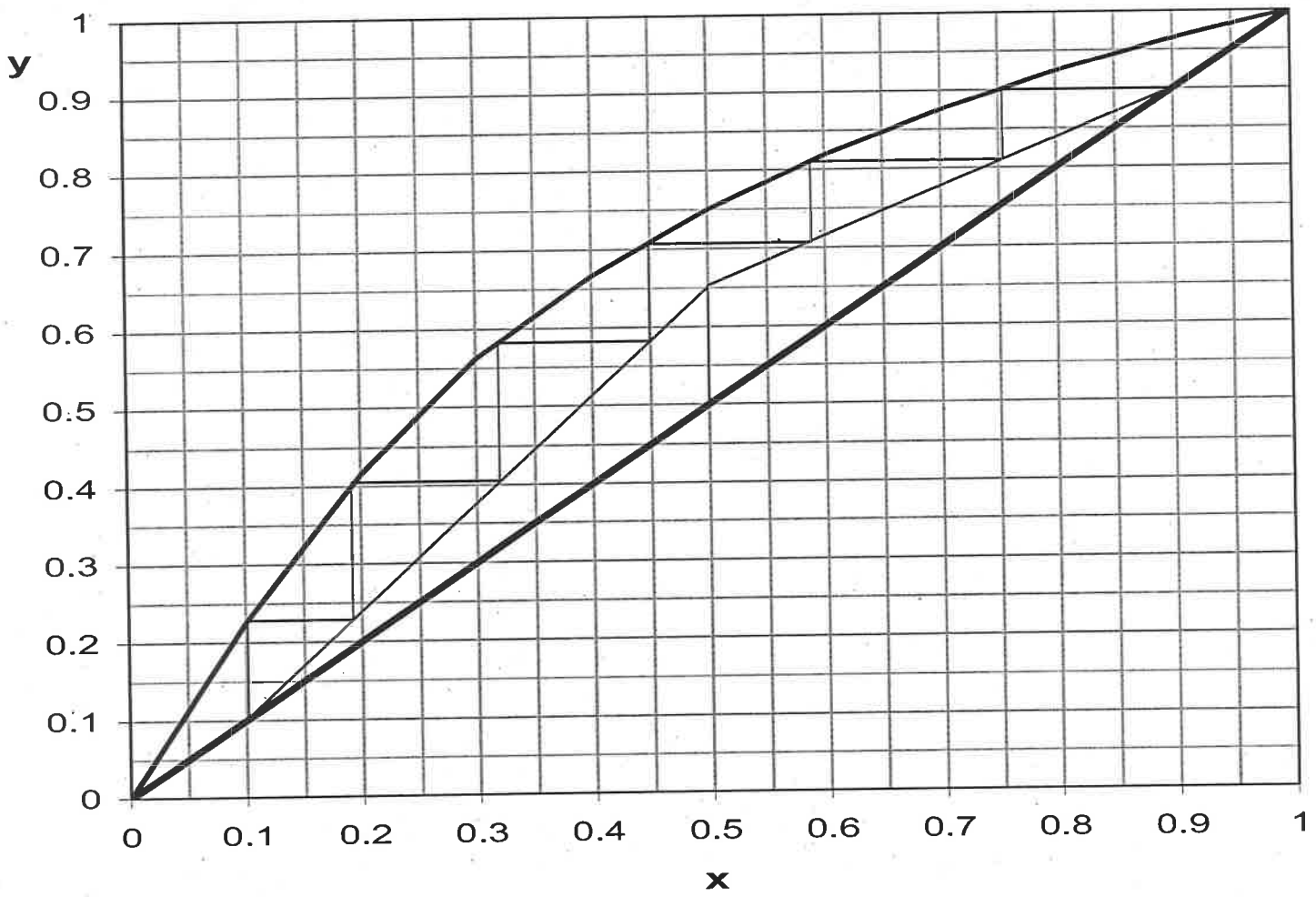
Question # 7 Diffusion **(15 points)**

A beaker having a diameter of 10 cm contains water at 25°C. The water level is 1 cm below the beaker rim.

The beaker is in a laboratory where the temperature is 25°C and air has a relative humidity H_R = 40%.

Calculate the initial rate of water evaporation supposing that the space between the beaker rim and the water level acts as a stagnating layer.

The diffusivity of water vapour in air a 25°C is: $D = 0.256\ cm^2/s$.


y
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
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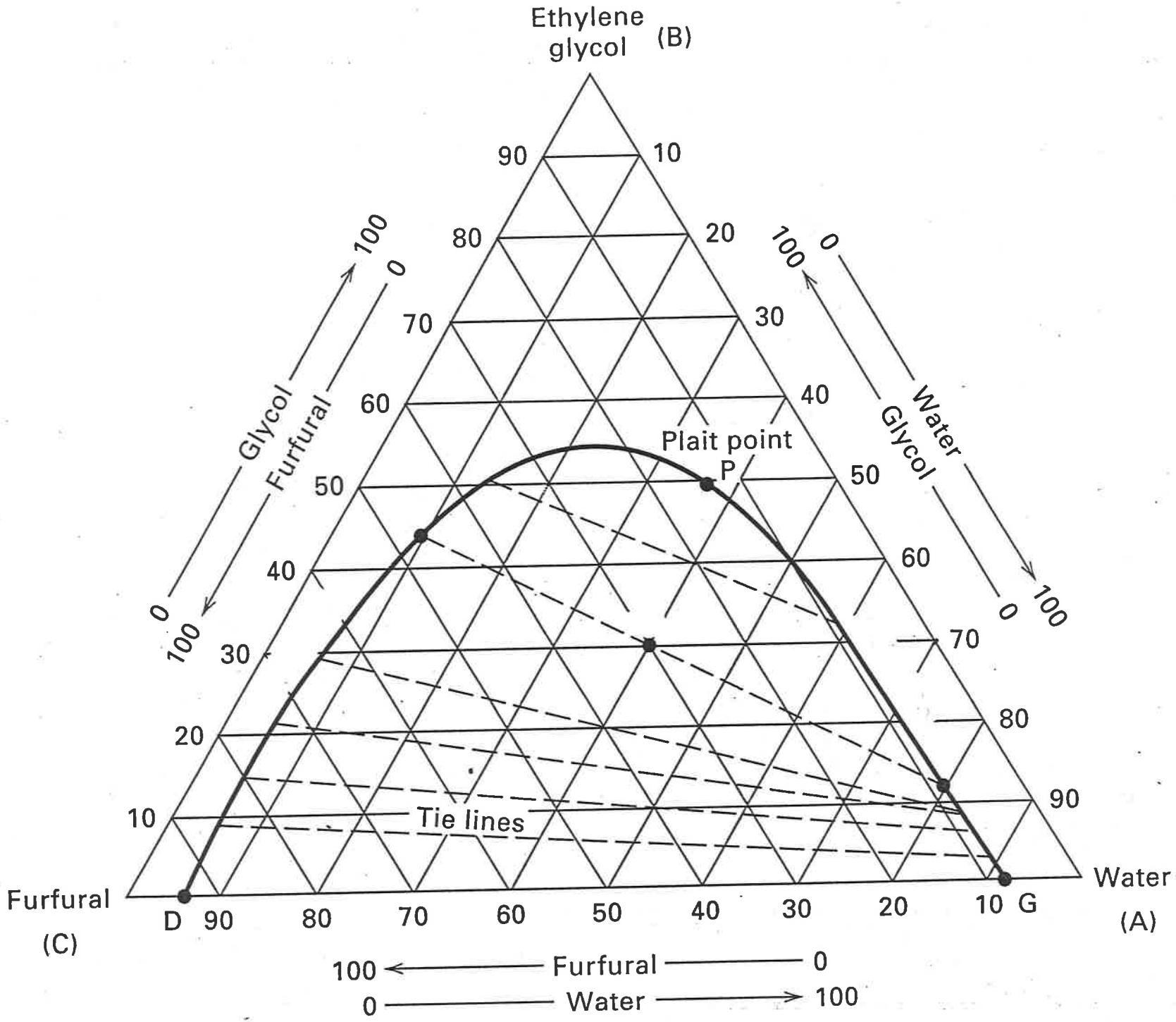
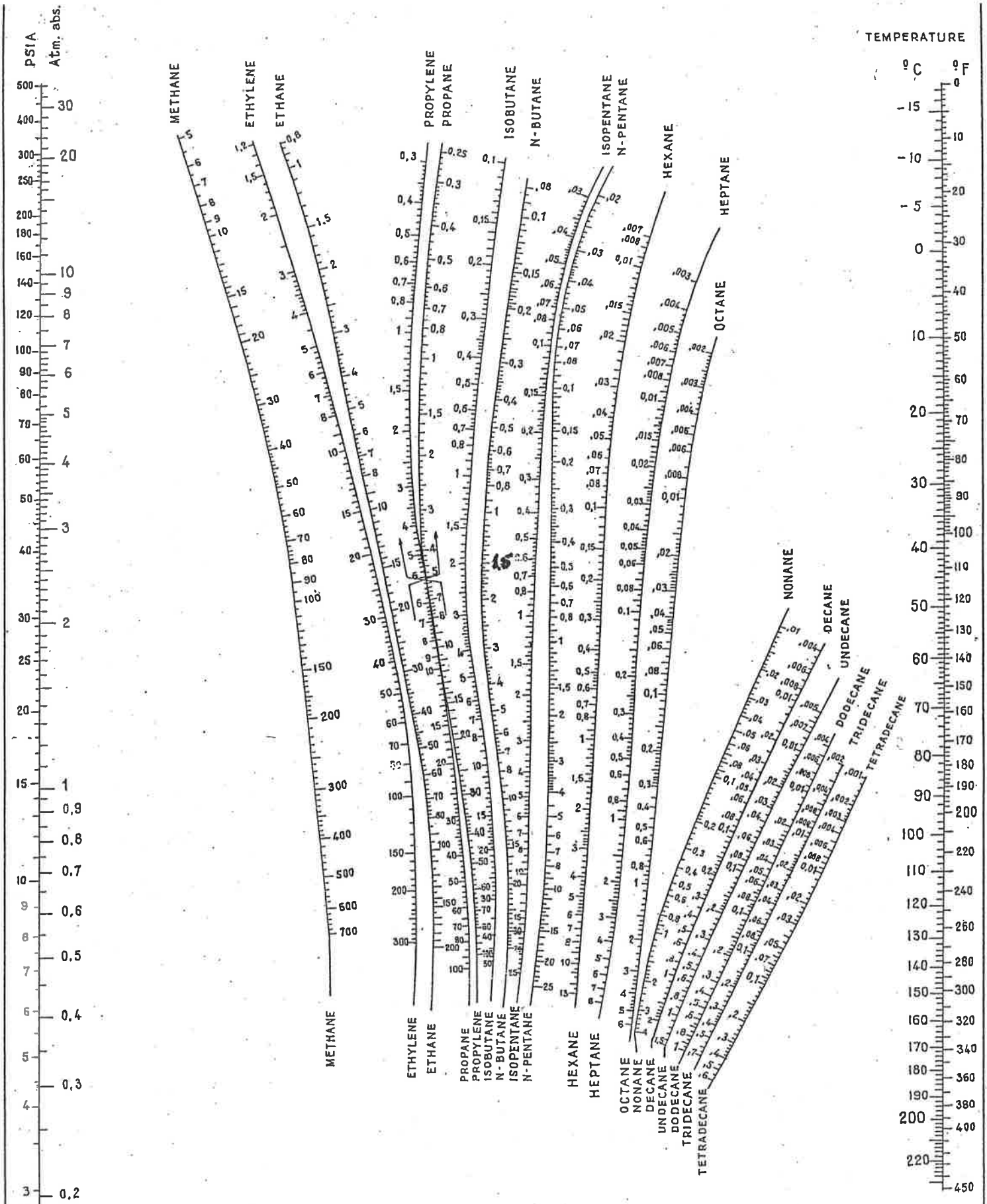
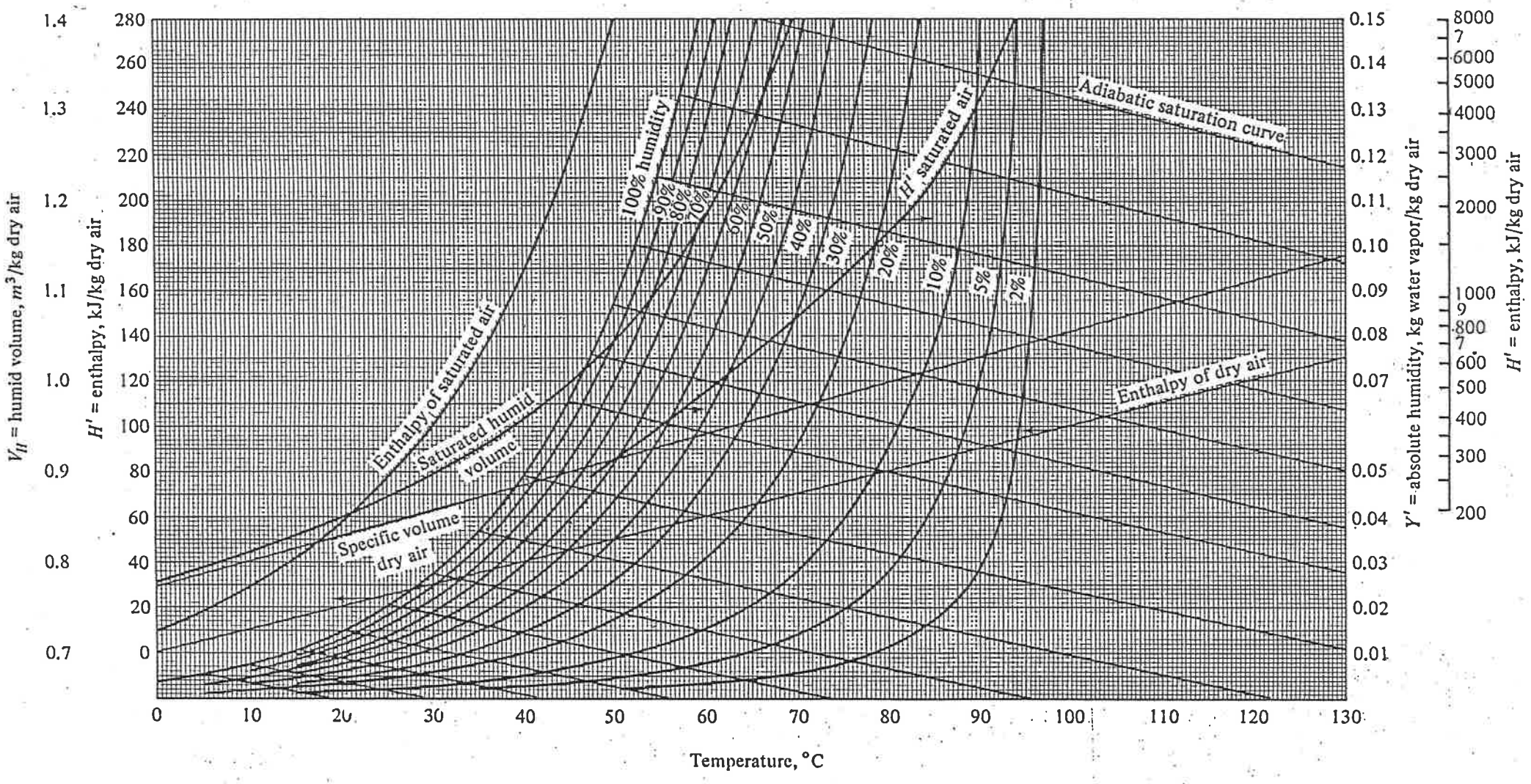
1
x


Ethylene glycol (B)
90
10
80
20
70
30
60
40
50
50
40
60
30
70
20
80
10
90
Glycol
Furfural
Water
Glycol
Plait point
P
Tie lines
Furfural (C)
D
Water (A)
G
100 ← Furfural → 0
0 ← Water → 100



COEFFICIENTS D'EQUILIBRE DES HYDROCARBURES

(Scheibel & Jenny)



Psychrometric chart for air-water vapor, 1 std atm abs, in SI units.