ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2013 SESSION

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

04 – CHEM A3 MASS TRANSFER OPERATIONS

Question # 1 - Absorption (18 pts)

Small quantities of NH_3 found in the air of a workshop where surface of steel plates are treated at elevated temperature by NH_3 have to be reduced considerably. Indeed, people living in the vicinity complain about the (ammonia) smell, especially when the weather is dry.

Make a preliminary design of an absorption column to treat 380ft^3/min (20°C, 1 atm) of air containing 1.6 vol% NH_3.

90% of NH_3 found in the air has to be removed by using water at the flow rate L' = 1.5 L'min.

For low NH_3 concentrations following linear equations may be used:

$$Y = KX, \text{ where } K = 0.76$$

For calculations a distance between stages of 12in is suggested.

Finally, based on your calculations fill up the table below:

Number of stages by the Kremser method	
Column height	
Column diameter for a factor of 0.8	

* The pertinent data are given at the end of the exam.

Question # 2 – Equilibrium (10 points)

In a petrochemical plant 100 kmol/h of equimolar mixture propane – n-pentane is fed through pipes kept at 20°C. The pressure in the pipes is 10 atm.

Calculate the amount of ethane that can be added to the mixture propane – n-pentane without a formation of vapour pocket. The total liquid flow rate must not change.

* The pertinent data are given at the end of the exam.

Question# 3 - Distillation- graphical method (14 points)

To escape a bad weather in Montreal, your colleague has preferred to spend few days in a sun of Cuba. He started to solve a problem on distillation but Ieft you to finish the calculations. This distillation problem treats the separation of 100 kmol/h of a mixture hexane-heptane. He left you the results in the form of the figure shown below.

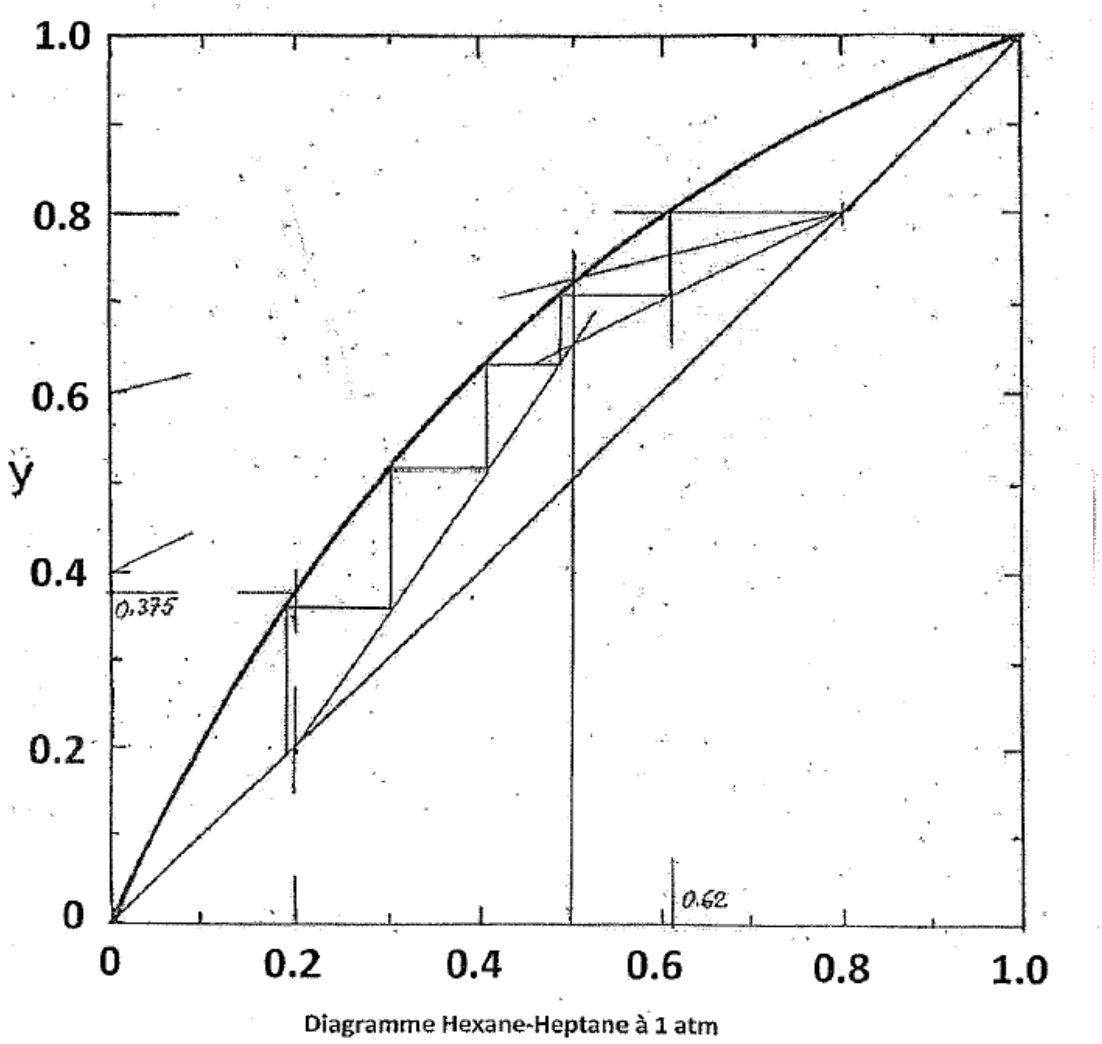


Diagramme Hexane-Heptane à 1 atm

To be able to fill the following Table, you should verify and complete his results. All your results have to be presented clearly.

Flow rate of D	
Flow rate of B	
Flow rate of $\overline{L}$ and of $\overline{V}$	
Number of theoretic stages without reboiler	
The ratio R / R_{min}	
N_{min}	
Temperature of equilibrium flows that leave the last stage (top of the column)	T_{vapor}: T_{liquid}:

* The pertinent data are given at the end of the exam.

Question # 4 - Distillation – FUG method (18 points)

To verify the results obtained by the graphical method you should solve the problem "Distillation – graphical method" by the method FUG (Fenske-Underwood-Gilliland).

Specifically, you should only determine: Nmin, Rmin, R and N.
For the calculations you should use the reflux rate L/D = 3Rmin.

* The pertinent data are given at the end of the exam.

Question # 5 - Evaporation (15 points)

Humidity of air in a greenhouse for exotic plants is assured by water vapour coming from a water pool.

The water temperature in the pool is 20°C. The air temperature in the hothouse is 30°C, relative humidity RH = 50% and the pressure is 1 atm.

It is planned to triple the number of plants. This will triple the water vapour consumption.

To maintain the same humidity and to satisfy the triple consumption, it will be necessary to triple the water vapour generation.

Calculate for the new conditions the new water temperature in the pool. Assume that the temperature and humidity in the hothouse as weil as the stagnation layer above the water surface do not change.

* The pertinent data are given at the end of the exam.

Question #6 – Liquid-Liquid Extraction (15 points)

Batch L – L extraction of 400 kg of aqueous 47.5 mass% acetone solution by using MIK solvent has been carried out.

Obtained extract had the following composition:

- 31 mass% acetone
- 6 mass% water
- 63 mass% MIK

Calculate:

–the composition of raffinate;
–the amount of solvent (MIK) used for extraction;
–the amount of extract;
–the composition of extract without the solvent (MIK).

* The pertinent data are given at the end of the exam.

Question #7 - Humidity (10 points)

To avoid during summer water condensation in the tunnels of the metro in Caracas the incoming air has to be first dehumidified by cooling.

In the middle of summer, the air to be dehumidified is characterized by dry-bulb temperature $T = 35^{\circ}C$ and a wet-bulb temperature $T = 30^{\circ}C$.

Calculate in kg/min the amount of water that will be removed by condensation from air provided 100 m^3/min humid air will be cooled to $20^{\circ}C$.

* The pertinent data are given at the end of the exam.

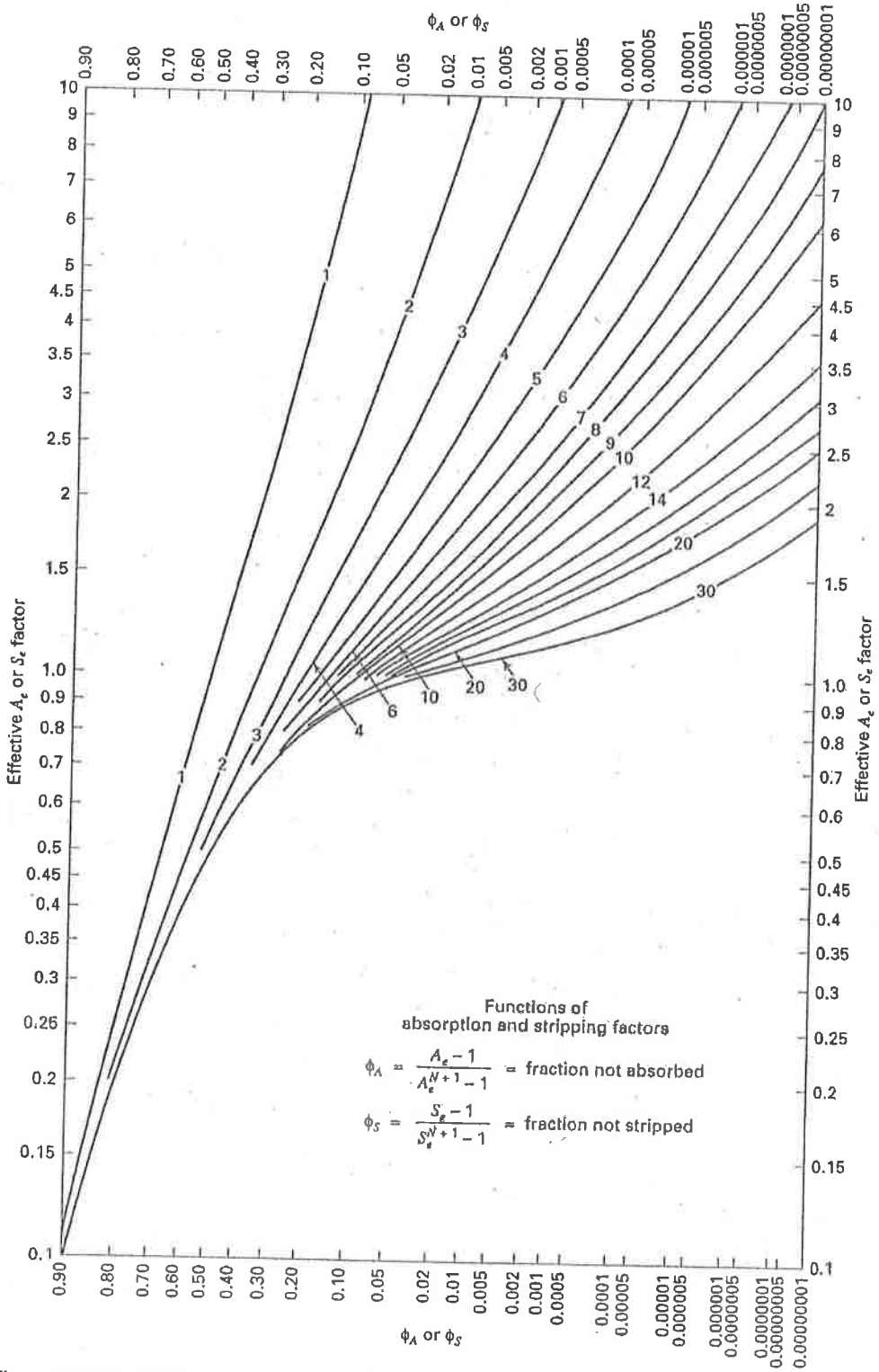


Figure 5.9 Plot of Kremser equation for a single-section countercurrent cascade.
[From W. C. Edmister, *AIChE J.*, 3, 165–171 (1957).]

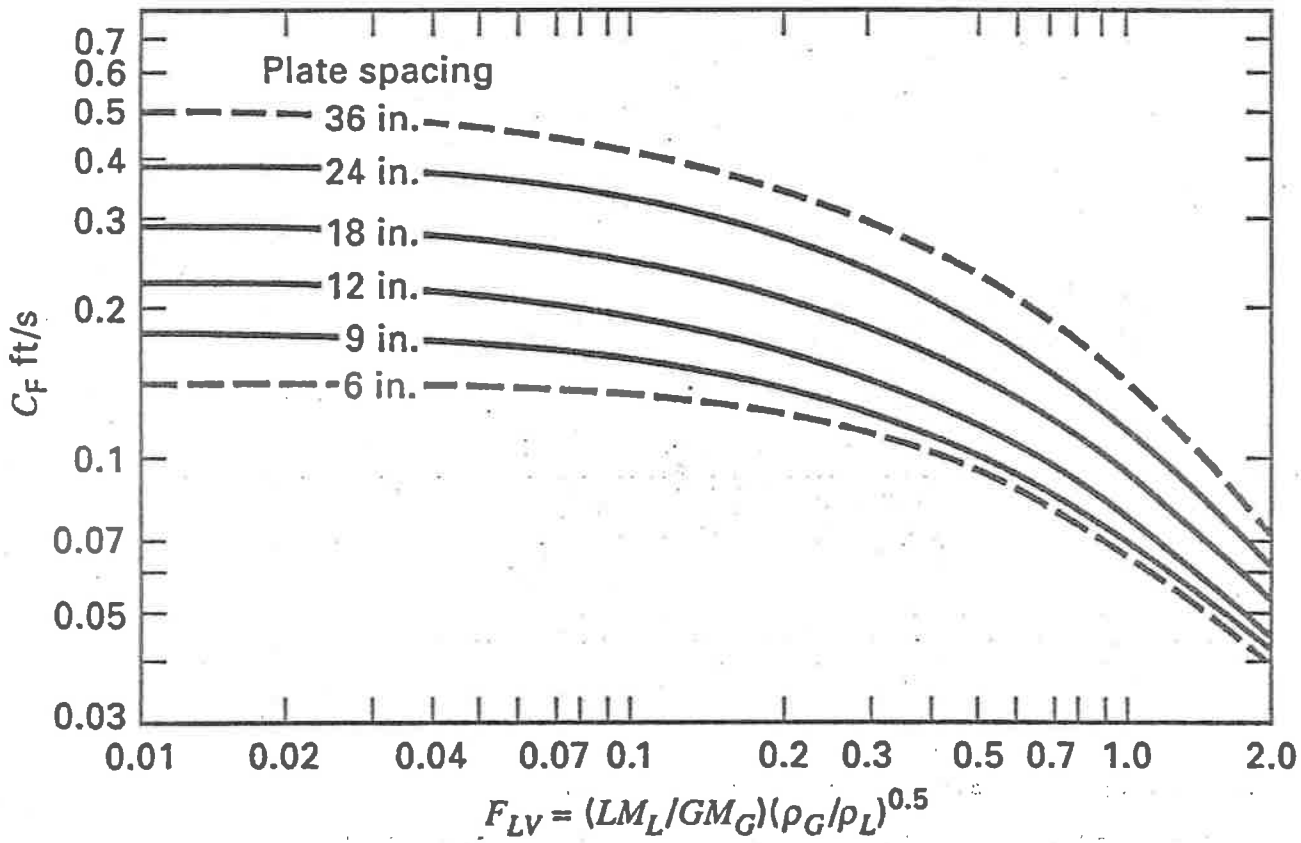
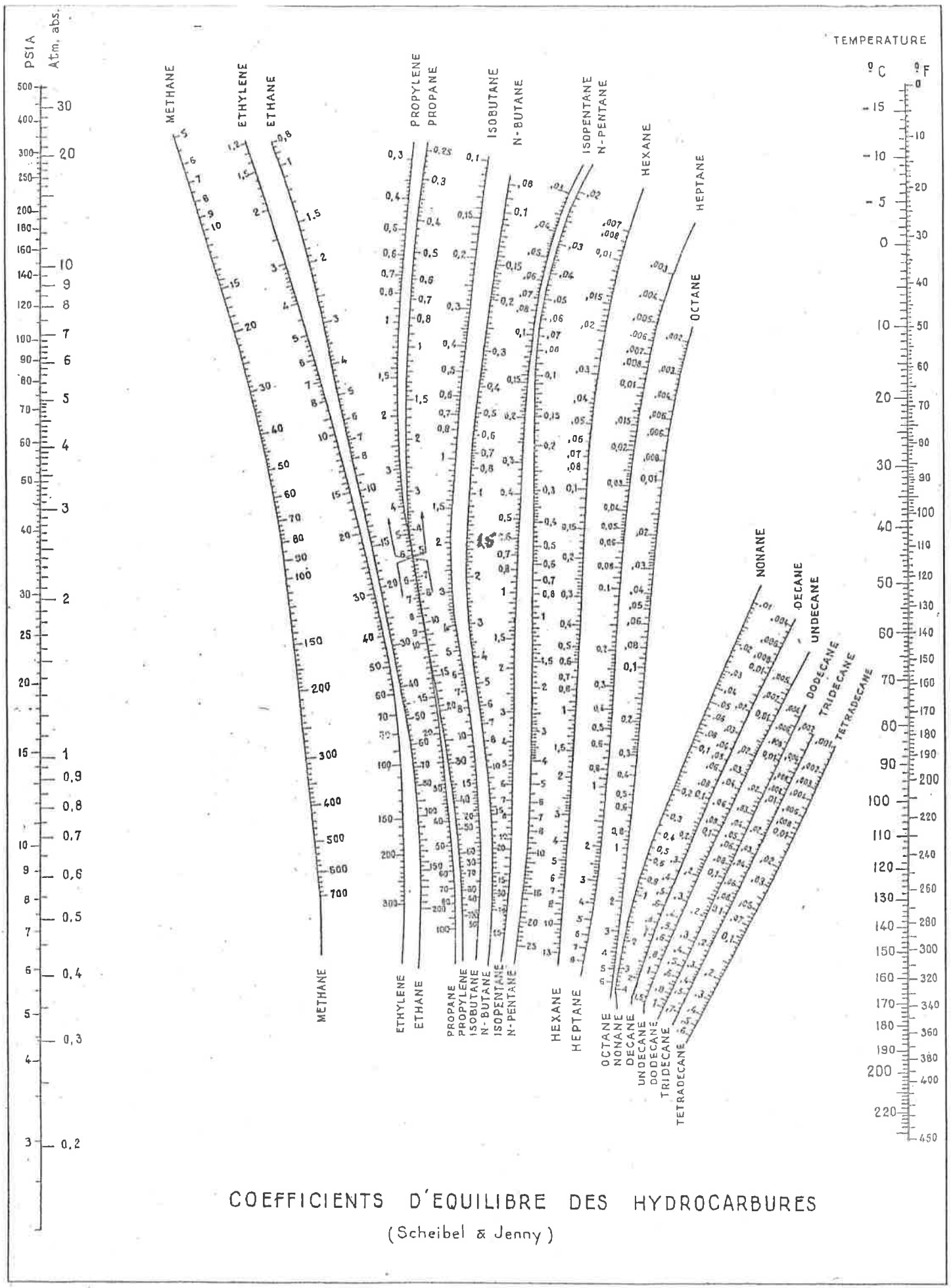


Figure 6.24 Entrainment flooding capacity in a trayed tower.



COEFFICIENTS D'EQUILIBRE DES HYDROCARBURES

(Scheibel & Jenny)

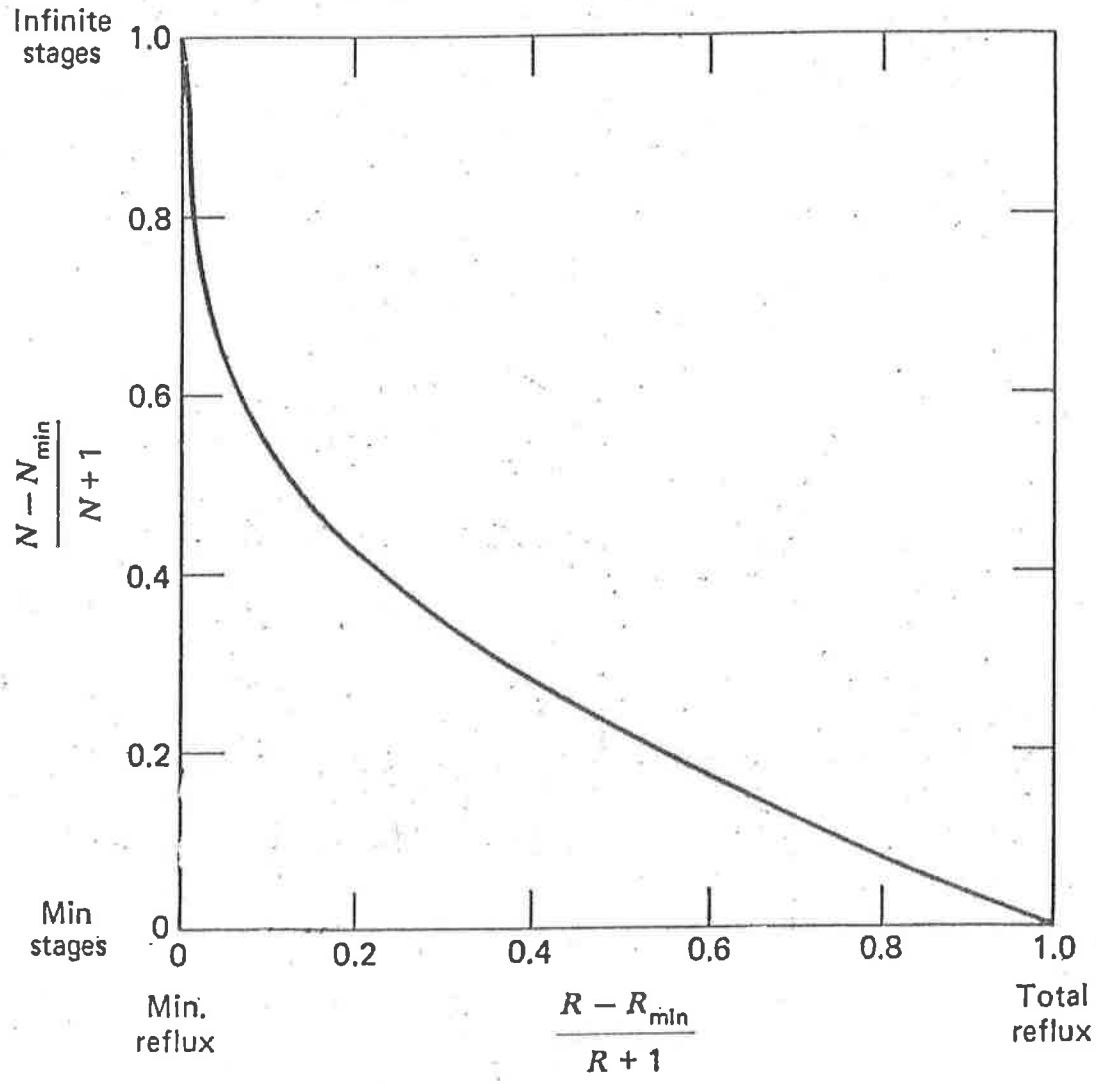


Figure 12.12. Gilliland correlation with linear coordinates.

Si deux températures et leurs pressions correspondantes sont impliquées, l'équation de Clausius-Clapeyron peut s'exprimer ainsi :

$$\ln(\frac{p_2^o}{p_1^o}) = -\frac{\Delta H_v}{R} \cdot (\frac{T_1 - T_2}{T_1 \cdot T_2})$$

Antoine

Équation empirique qui corrèle les données de tension de vapeur et la température :

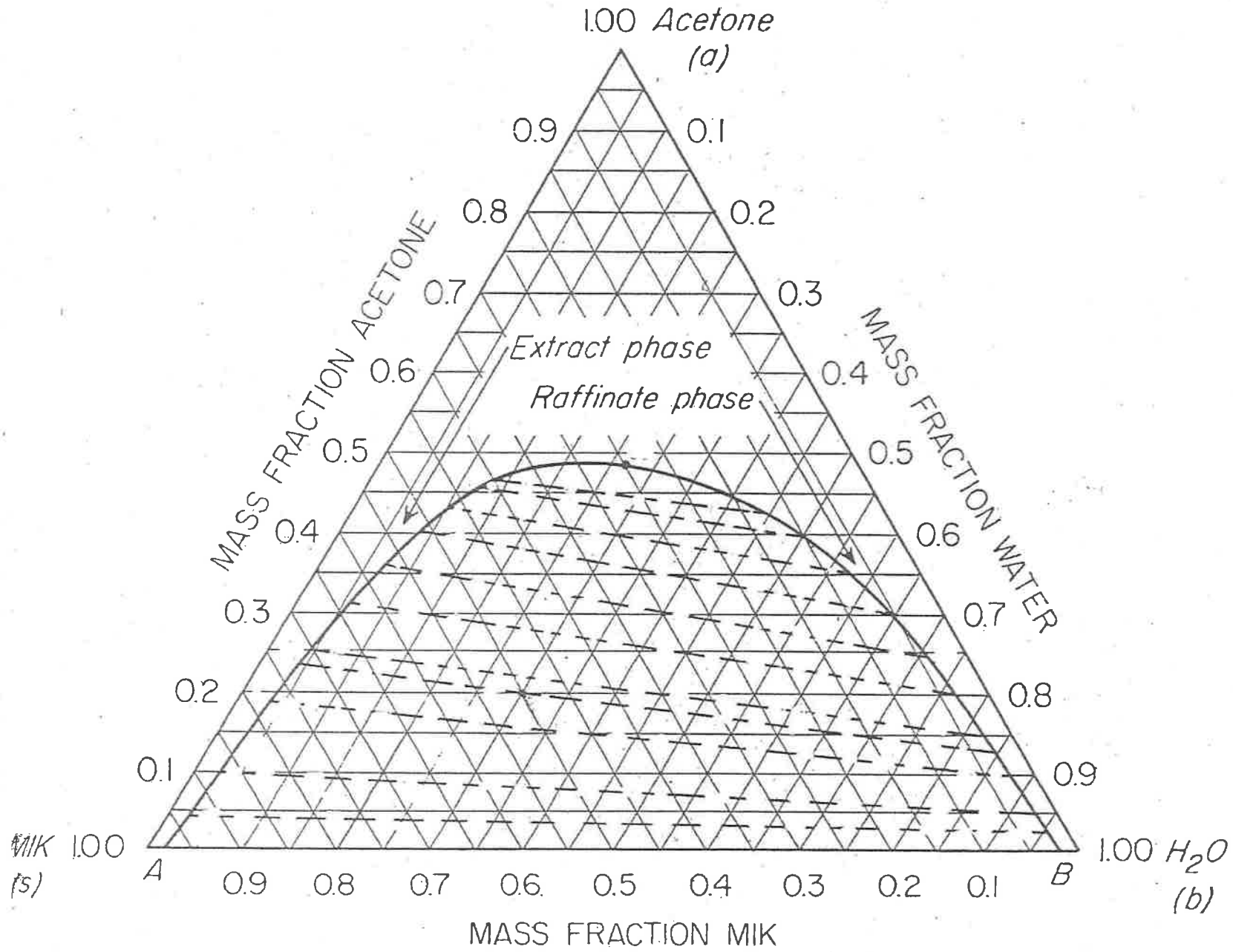
$\log_{10} p^* = A - \frac{B}{T+C}$ où A, B et C sont des constantes propres à chaque substance

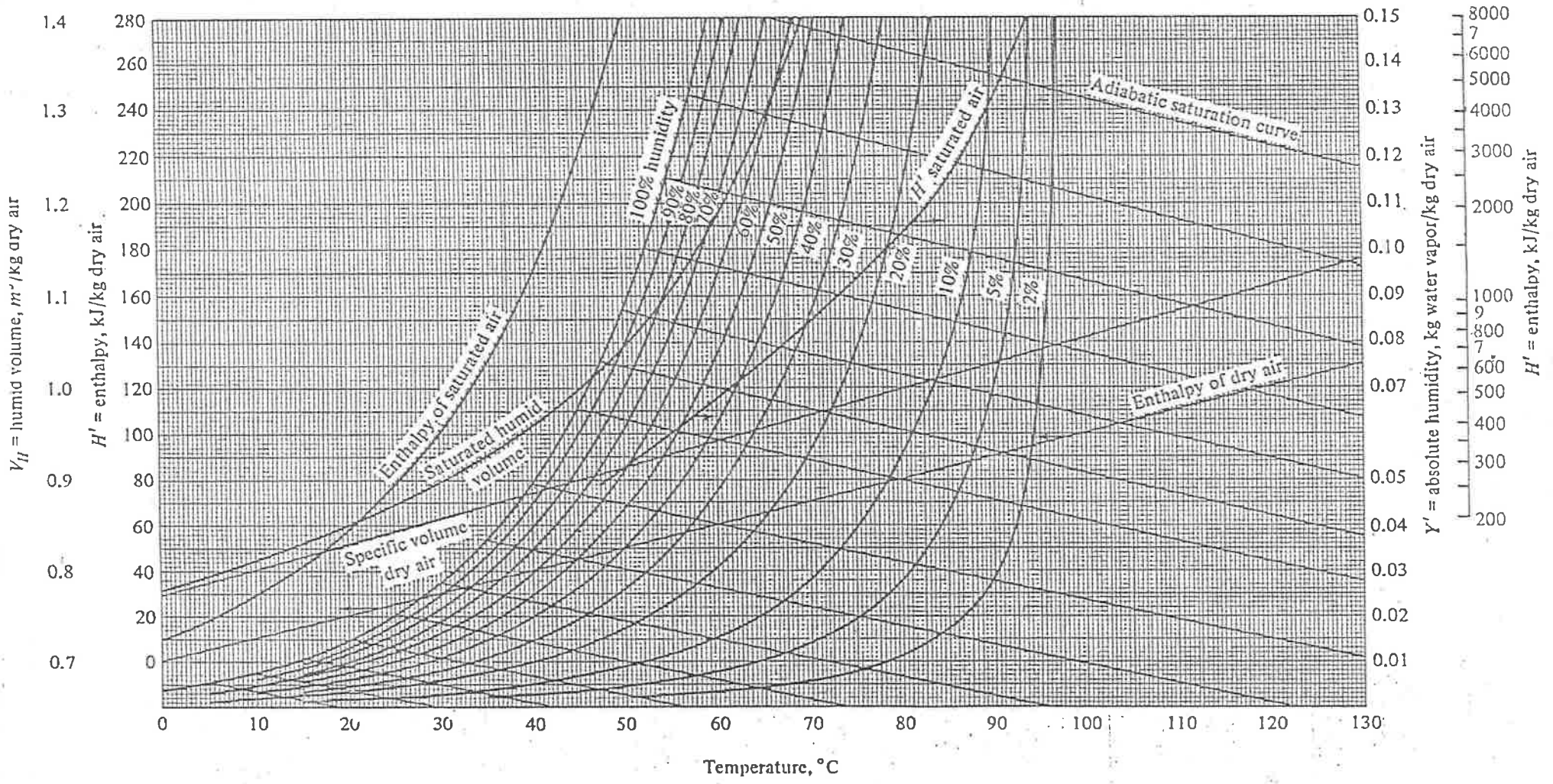
T est généralement exprimé en °C

Les constantes A, B et C sont données dans la littérature et le tableau 1.5 en résume quelques-unes ; P^* est en mm Hg.

Tableau 1.5. Constantes pour l'équation d'Antoine

Substance	Formule	Températures (C)	A	B	C
Acetaldehyde	C_2H_4O	-45 à +70	6.81089	992.0	230
Acide acétique	$C_2H_4O_2$	0 à +36	7.80307	1651.2	225
		+36 à 170	7.18807	1416.7	211
Acétone	C_3H_6O	—	7.02447	1161.0	224
Ammoniac	NH_3	-83 à +60	7.55466	1002.711	247.885
Benzène	C_6H_6	—	6.90565	1211.033	220.79
Tétrachlorure de carbone	CCl_4	—	6.93390	1242.43	230.0
Chlorobenzène	C_6H_5Cl	0 à +42	7.10690	1500.0	224.0
		+42 à +230	6.94504	1413.12	216.0
Chloroforme	$CHCl_3$	-30 à +150	6.90328	1163.03	227.4
Cyclohexane	C_6H_{12}	-50 à +200	6.84498	1203.526	222.863
Acétate d'éthyl	$C_4H_8O_2$	-20 à +150	7.09808	1238.71	217.0
Alcool éthylique	C_2H_6O	—	8.04494	1554.3	222.65
Éthylbenzène	C_8H_{10}	—	6.95719	1424.255	213.206
n-heptane	C_7H_{16}	—	6.90240	1268.115	216.900
n-hexane	C_6H_{14}	—	6.87776	1171.530	224.366
Alcool méthylique	CH_4O	-20 à +140	7.87863	1473.11	230.0
n-pentane	C_5H_{12}	—	6.85221	1064.63	232.0
Isopentane	C_5H_{12}	—	6.78967	1020.012	233.097
Styrène	C_8H_8	—	6.92409	1420.0	206
Toluène	C_7H_8	—	6.95334	1343.943	219.377
Eau	H_2O	0 à 60	8.10765	1750.286	235
		60 à 150	7.96681	1668.21	228.0


1.00 Acetone
(a)
0.9
0.1
0.8
0.2
0.7
0.3
0.6
0.4
0.5
0.5
0.4
0.6
0.3
0.7
0.2
0.8
0.1
0.9
MASS FRACTION ACETONE
MASS FRACTION WATER
Extract phase
Raffinate phase
MIK 1.00
(s)
A
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
B
1.00 H_2O
(b)
MASS FRACTION MIK



(a)

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