Pool Boiling Correlations

- **Rohsenow (1952)** 'A Method for correlating heat transfer data for surface boiling in liquids'. *Trans ASME, 74, 969.*

  Rohsenow correlation includes surface effects. In single phase

  Nu = f(Re, Pr)

  In boiling, what is the length scale and the velocity for calculating Reynolds number?

  The velocity is taken as the liquid velocity, which is to supply the vapour being produced

$$u = \frac{q''_w}{\rho_f h_{fg}}$$

  the length scale is taken to be

$$L = \left[\frac{\sigma}{g(\rho_f - \rho_g)}\right]^{0.5}$$

Pool Boiling Correlations

Rohsenow correlation has an arbitrary constant C_{sf} to account for the nucleation properties of any particular liquid-surface combination

Thus:

$$Nu = \frac{1}{C_{sf}} \mathrm{Re}^{(1-n)} \mathrm{Pr}_f^{-m}$$

The above can be rearranged to give:

$$\frac{c_{p,f} \Delta T_{sat}}{h_{fg}} = C_{sf} \left\{ \frac{q''_w}{\mu_f h_{fg}} \left[\frac{\sigma}{g(\rho_f - \rho_g)} \right]^{0.5} \right\}^n \left(\mathrm{Pr}_f \right)^{m+1}$$

The original equation had n = 0.33 and m = 0.7

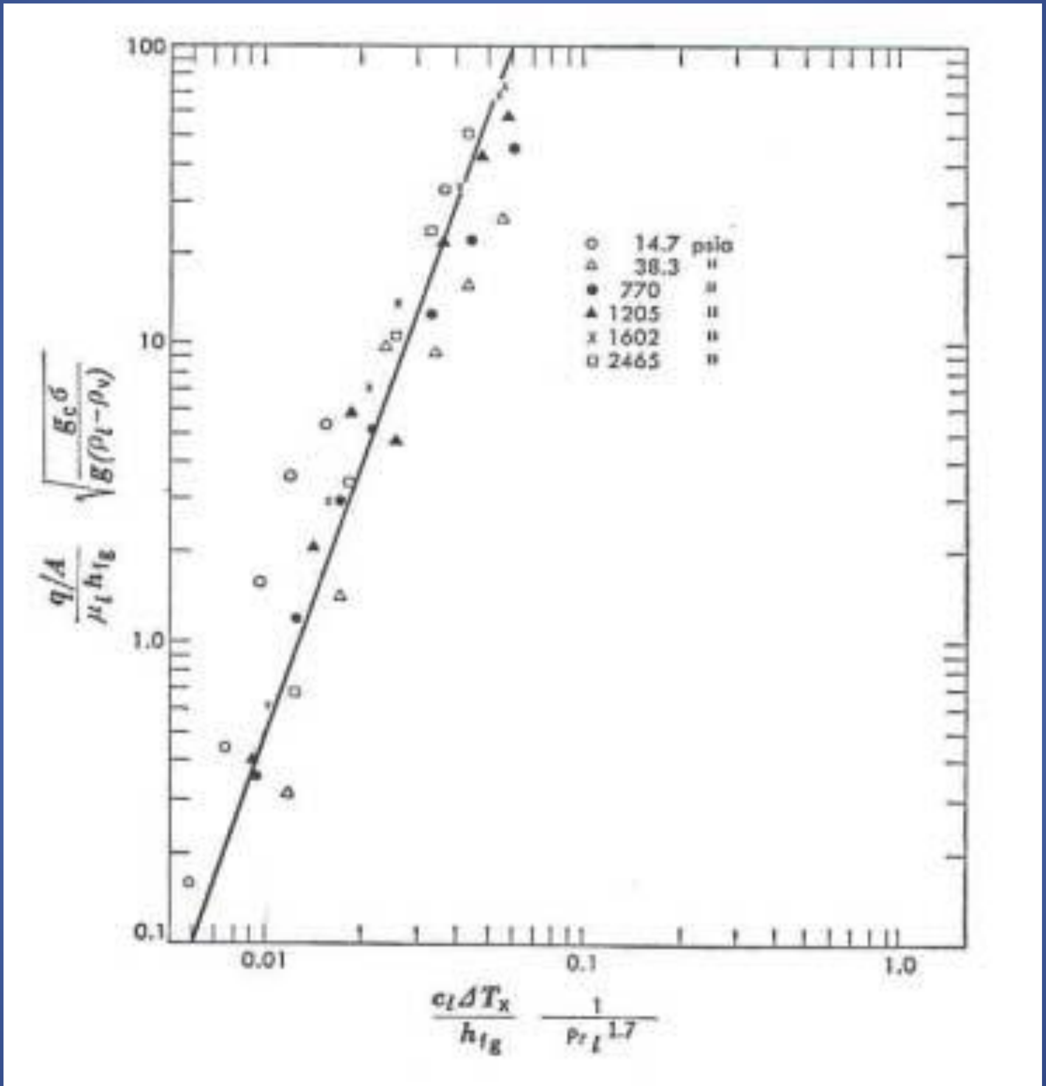
Rohsenow recommended a value of m to be zero for *water only*.

Values of C_{sf} for various surface-fluid combination is presented in the next table. If value is not available for a particular surface-fluid combination, a value of 0.013 can be used as a first approximation.

Pool Boiling Correlations

Liquid-Surface Combination	C_{sf}
Water on teflon-pitted SS	0.0058
Water on scored copper	0.0068
Water on ground and polished SS	0.0080
Water on emery polished copper	0.0128
Water on chemically etched SS	0.0133
Water on mechanically polished SS	0.0132
Water on emery polished paraffin-treated copper	0.0147
n-pentane on lapped copper	0.0049
n-pentane on polished copper	0.0127
n-pentane on emery polished copper	0.0154
Carbon tetrachloride on emery polished copper	0.0070
Water on nickel (vertical tube)	0.006
Water on SS (horizontal tube)	0.015/0.020
Water on copper (vertical tube)	0.013
Carbon tetrachloride on copper (vertical tube)	0.013
n-butyl alcohol on copper (vertical tube)	0.003

Correlation of pool boiling heat transfer data by method of Rohsenow



Pool Boiling Correlations

- **Forster – Zuber Correlation (1955)** 'Dynamics of vapor bubbles and boiling heat transfer'. *AIChE Journal, Vol. 1, pp. 531.*

$$q'' = 0.00122\left[\frac{k_l^{0.79}c_{pl}^{0.45}\rho_l^{0.49}}{\sigma^{0.5}\mu_l^{0.29}h_{fg}^{0.24}\rho_v^{0.24}}\right]\left[T_w - T_{sat}\left(P_l\right)\right]^{1.24}\Delta P_{sat}^{0.75}$$

ΔP_{sat} is the difference in saturation pressure corresponding to a difference in saturation temperature equal to the wall superheat, in Pascals.

Units: k_l ~ kW/m-K,

density ~ kg/m^{3},

specific heat ~ kJ/kg-K,

surface tension ~ N/m,

viscosity ~ Pa-s,

latent heat ~ kJ/kg,

Heat Flux ~ kW/m^2

Pool Boiling Correlations

- **Borishansky** (1969) 'in Problems of Heat Transfer and Hydraulics of Two-Phase media', Pergamon Press, New York, pp. 16-37.

$$q'' = (A*)^{3.33}\left[T_w - T_{sat}(P_l)\right]^{3.33}\left[F(P_{rl})\right]^{3.33}$$

Heat Flux ~ W/m^2

$F(P_{rl})$ is a function of reduced pressure, $P_{rl} = P/P_{crit}$

- **Mostinski** proposed the following:

$$(A*) = 0.1011(P_{crit})^{0.69} \quad , P_{crit} \text{ in bar}$$
$$F(P_r) = 1.8P_r^{0.17} + 4P_r^{1.2} + 10P_r^{10}$$

Pool Boiling Correlations

- **Stephan and Abdelsalam (1980)** 'Heat transfer correlations for natural convection boiling'. *IJHMT, Vol. 23, pp. 73-87.*

  Based on dimensional analysis and optimal fits to experimental data

$$\text{For water}: q'' = \left\{C_1\left[T_w - T_{sat}\left(P_l\right)\right]\right\}^{1/0.327}$$

$$\text{For hydrocarbons}: q'' = \left\{C_2\left[T_w - T_{sat}\left(P_l\right)\right]\right\}^{1/0.330}$$

$$\text{For cryogenic fluids}: q'' = \left\{C_3\left[T_w - T_{sat}\left(P_l\right)\right]\right\}^{1/0.376}$$

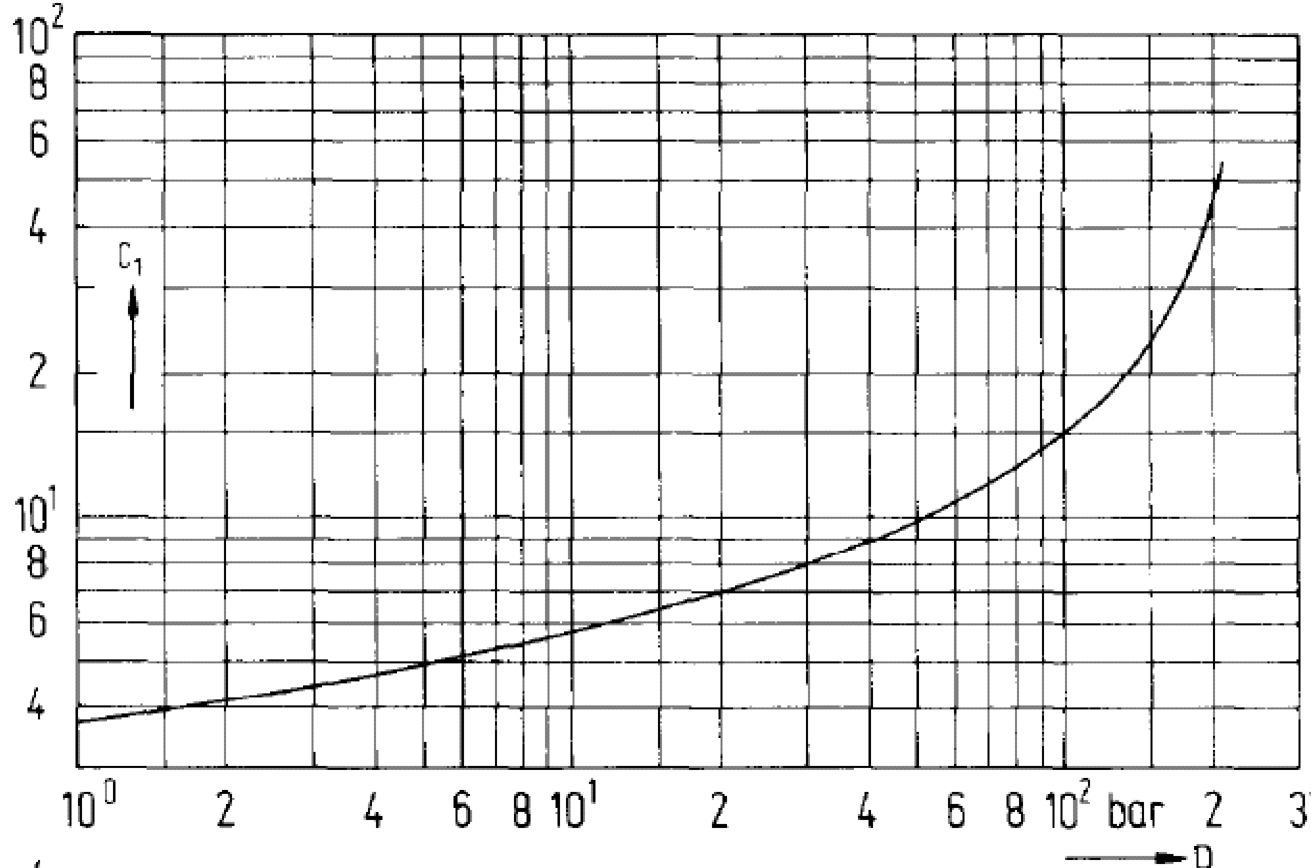
$$\text{For refrigerants}: q'' = \left\{C_4\left[T_w - T_{sat}\left(P_l\right)\right]\right\}^{1/0.255}$$

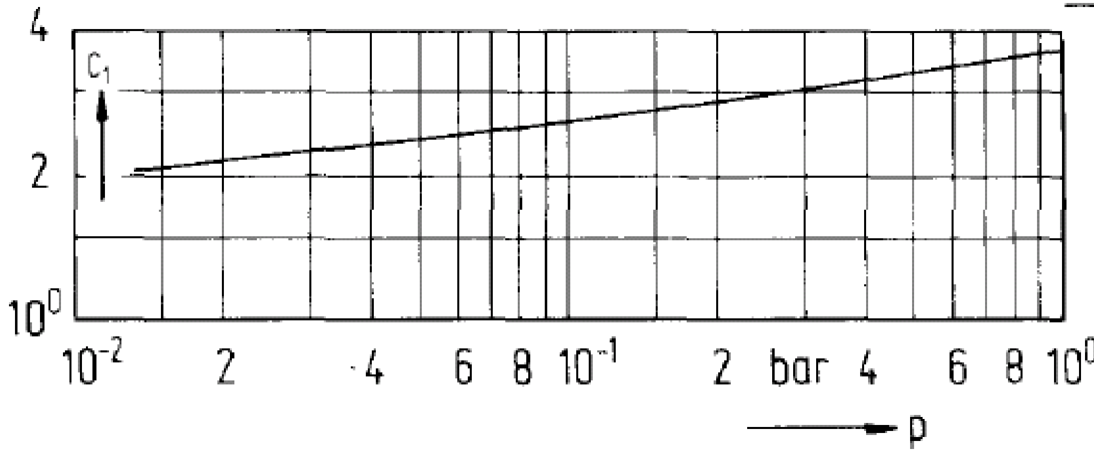
Units: k_l ~ W/m-K,

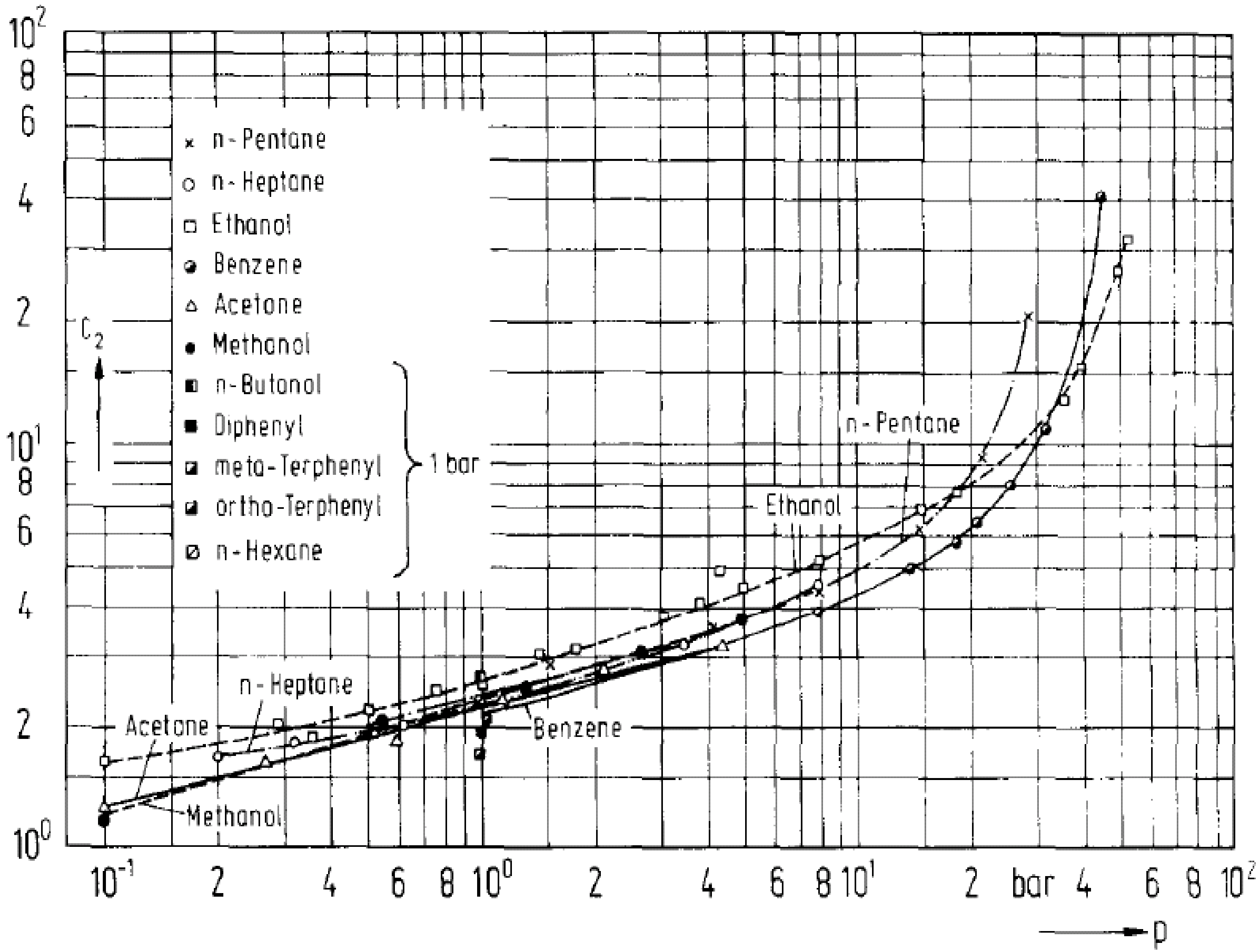
density ~ $kg/m^{3,}$

specific heat ~ kJ/kg-K,

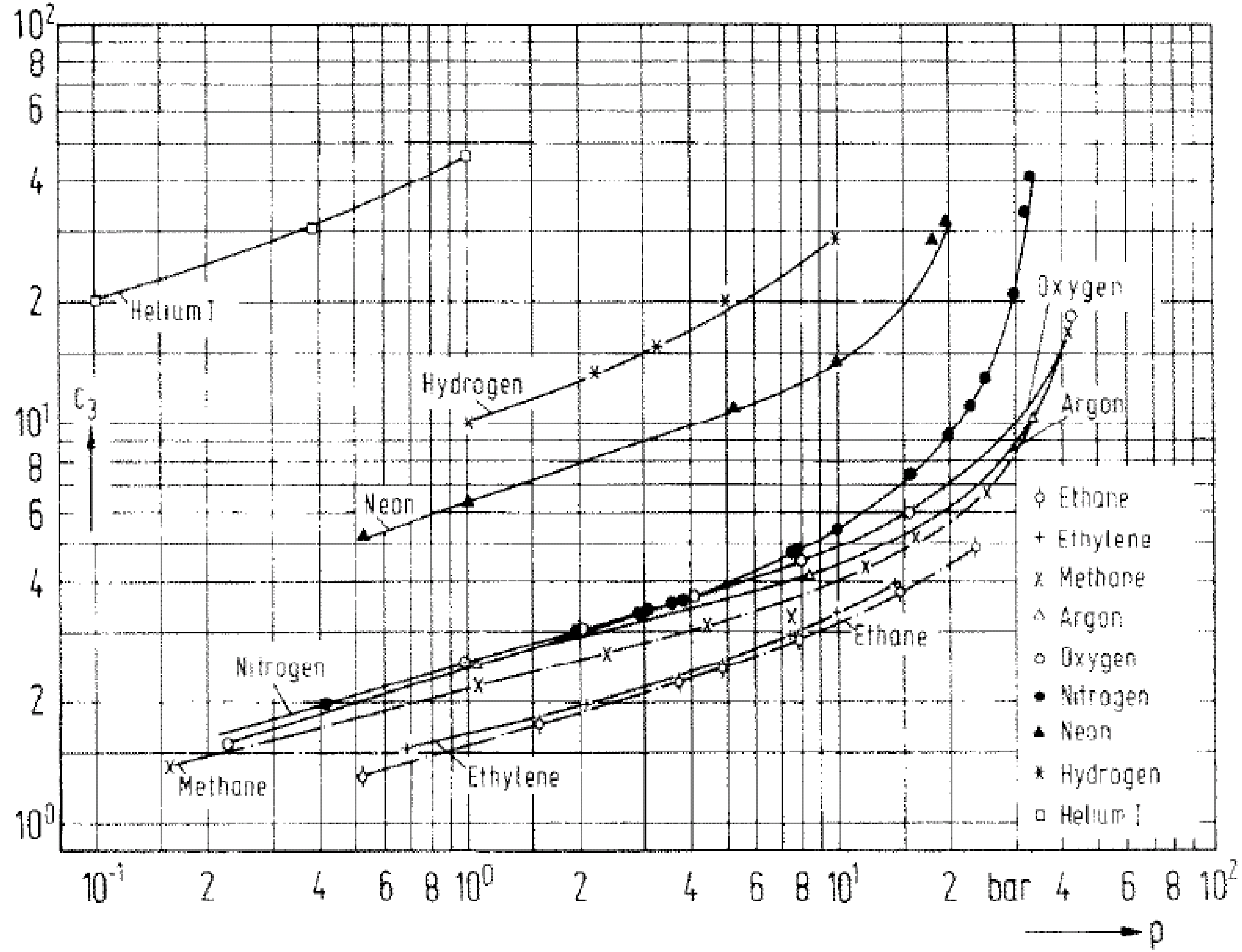
Heat Flux ~ W/m^2


10^2
8
6
4
c_1
2
10^1
8
6
4
10^0 2 4 6 8 10^1 2 4 6 8 10^2 bar 2 3
p

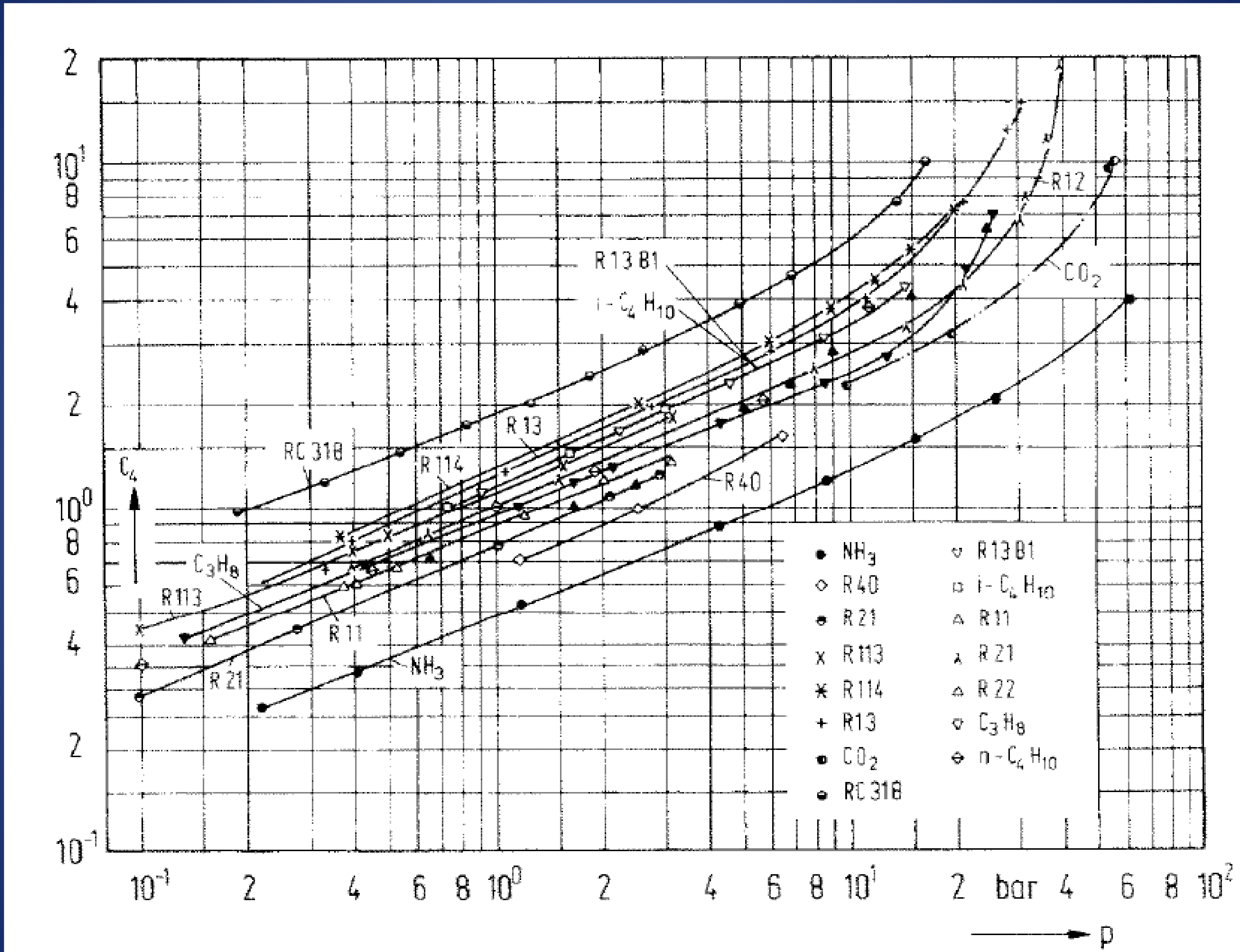

4
c_1
2
10^0
10^{-2} 2 4 6 8 10^{-1} 2 bar 4 6 8 10^0
p



10²
8
6
4
2
10¹
8
6
4
2
10⁰
C₂
× n-Pentane
○ n-Heptane
□ Ethanol
Benzene
△ Acetone
● Methanol
n-Butanol
Diphenyl
meta-Terphenyl
ortho-Terphenyl
n-Hexane
1 bar
n-Pentane
Ethanol
n-Heptane
Acetone
Benzene
Methanol
10⁻¹
2
4
6
8
10⁰
2
4
6
8
10¹
2
bar
4
6
8
10²
p



10^2
8
6
4
2
10^1
8
6
4
2
10^0
c_3
Helium I
Hydrogen
Neon
Oxygen
Argon
Nitrogen
Methane
Ethylene
Ethane
◊ Ethane
+ Ethylene
x Methane
△ Argon
○ Oxygen
● Nitrogen
▲ Neon
* Hydrogen
□ Helium I
10^{-1}
2
4
6
8
10^0
2
4
6
8
10^1
2
bar
4
6
8
10^2
p



C_4
RC 318
R 114
R 13
R 13 B1
i - C_4H_{10}
R 12
CO_2
R 40
C_3H_8
R 113
R 11
R 21
NH_3
NH_3
R 40
R 21
R 113
R 114
R 13
CO_2
RC 318
R 13 B1
i - C_4H_{10}
R 11
R 21
R 22
C_3H_8
n - C_4H_{10}
bar
p