Gases

(CH-3)

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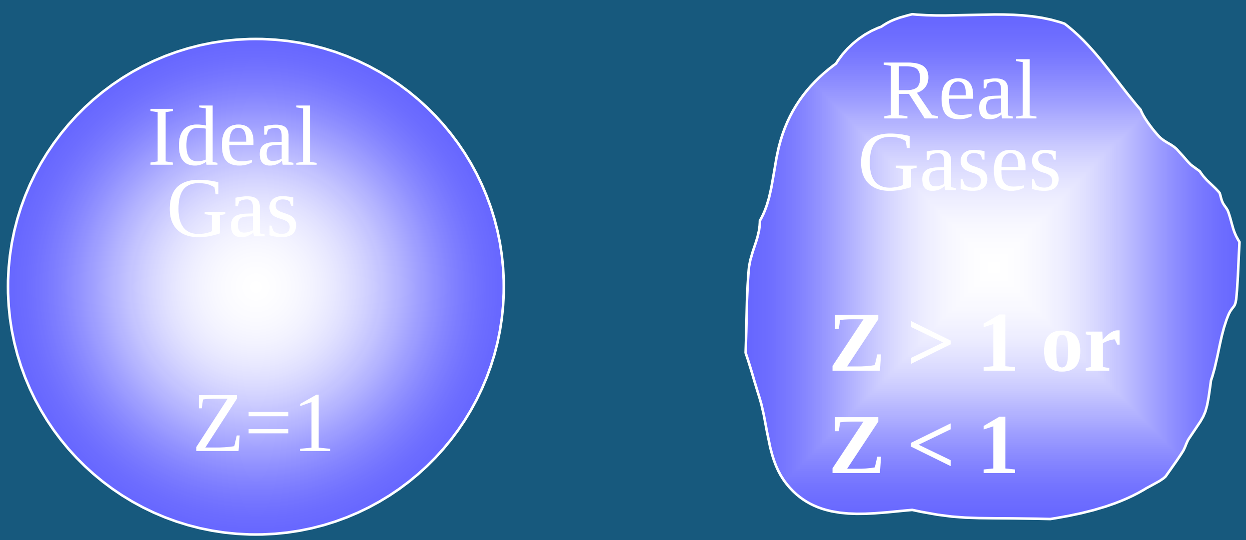
Real Gases

- $PV_M = RT$
- $\frac{PV_M}{RT} = 1$ (Ideal Gas)
- $\frac{PV_M}{RT} = Z$ (Real Gas)
- What is V_M ?
- $PV_M = ZRT$
- $PV = ZnRT$

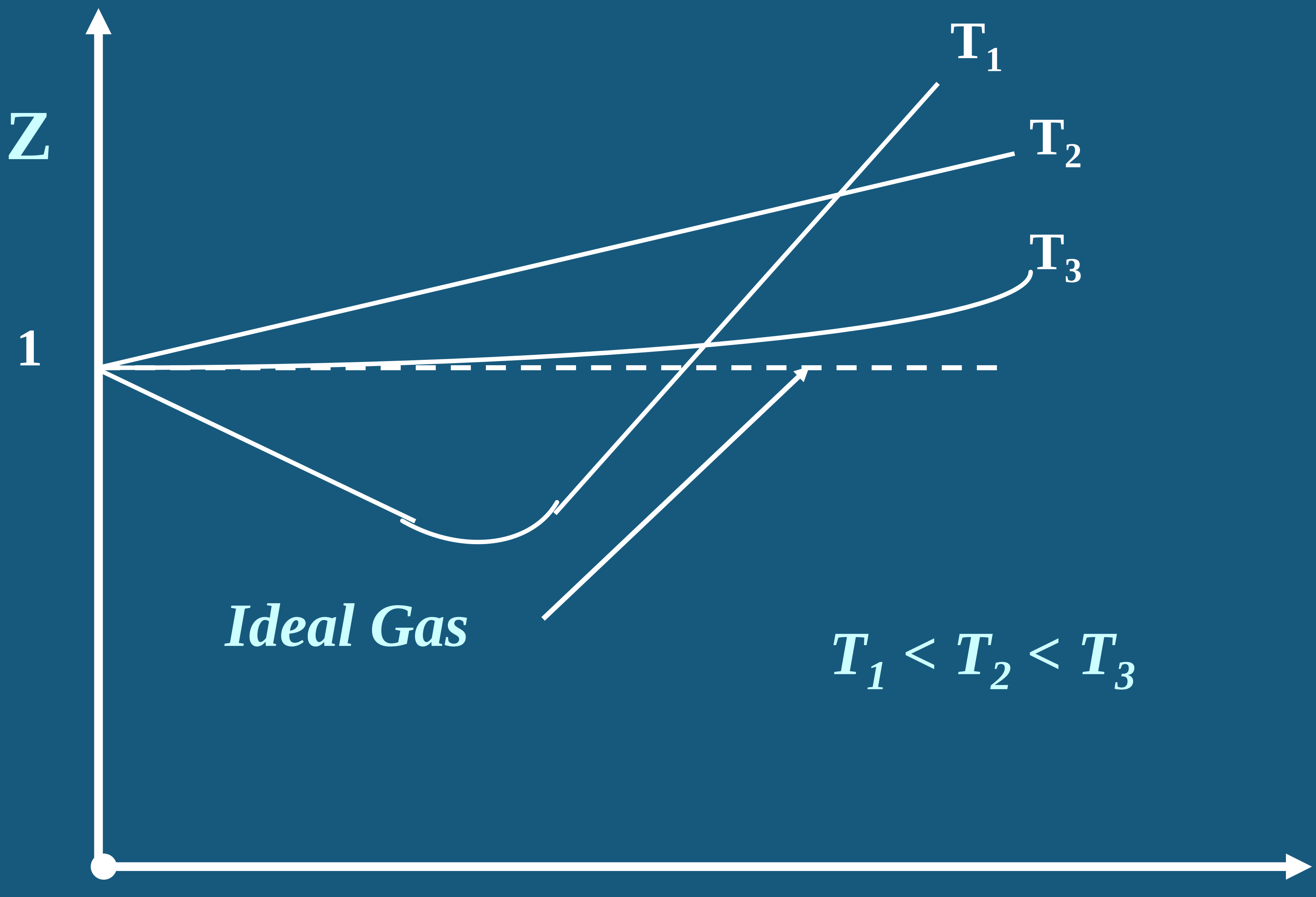
Compressibility Factor

The deviation from ideal-gas behavior can be properly accounted for by using the compressibility factor Z, defined as:

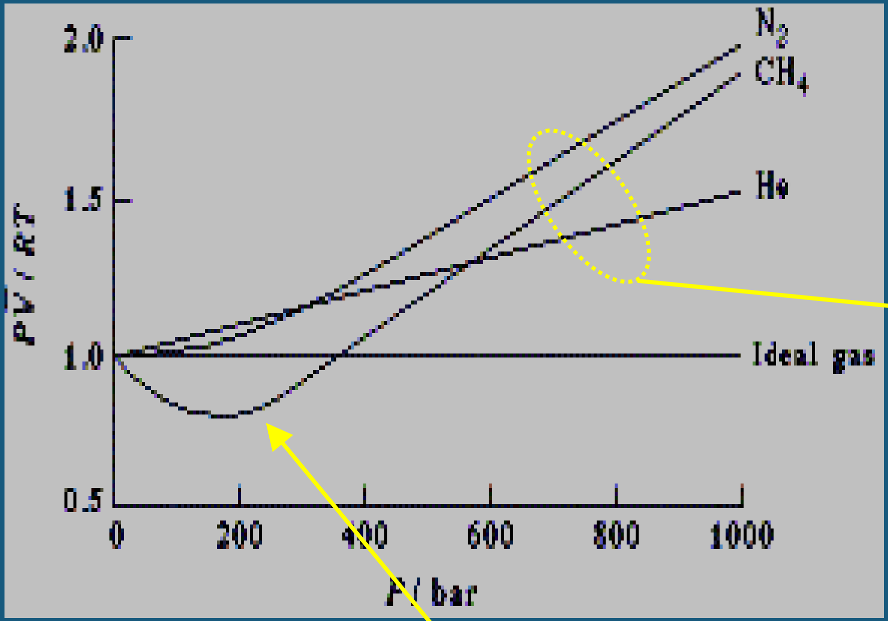
$$Z = \frac{V_{actual}}{V_{ideal}}$$



Compressibility Factor



Compressibility Factor



A high pressure, molecules are more influenced by repulsive forces.

$\bar{V}_{real} > \bar{V}_{ideal}$

$\therefore\ Z > 1$

The effect of molecular attraction causes:

$\bar{V}_{real} < \bar{V}_{ideal}$

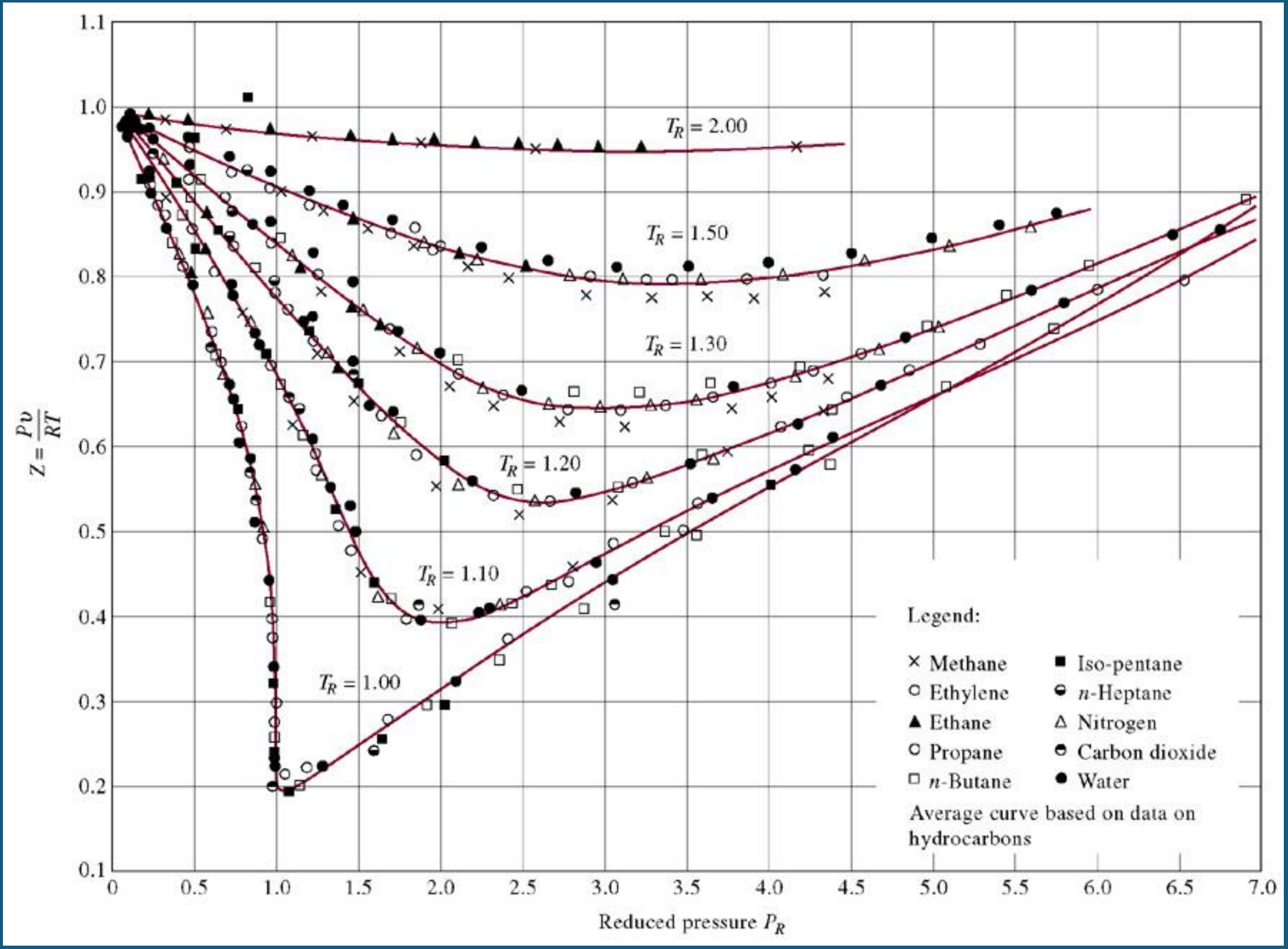
$\therefore\ Z < 1$

Compressibility Factor

- What is it really doing?
- It accounts mainly for two things
  - Molecular structure
  - intermolecular attractive forces
- Still we have a problem?
- Universal Z factor chart. (How?)
- The compressibility factor Z is approximately the same for all gases at the same reduced temperature and reduced pressure.

$$Z = Z(P_R, T_R) \text{ for all gases}$$

Compressibility Factor

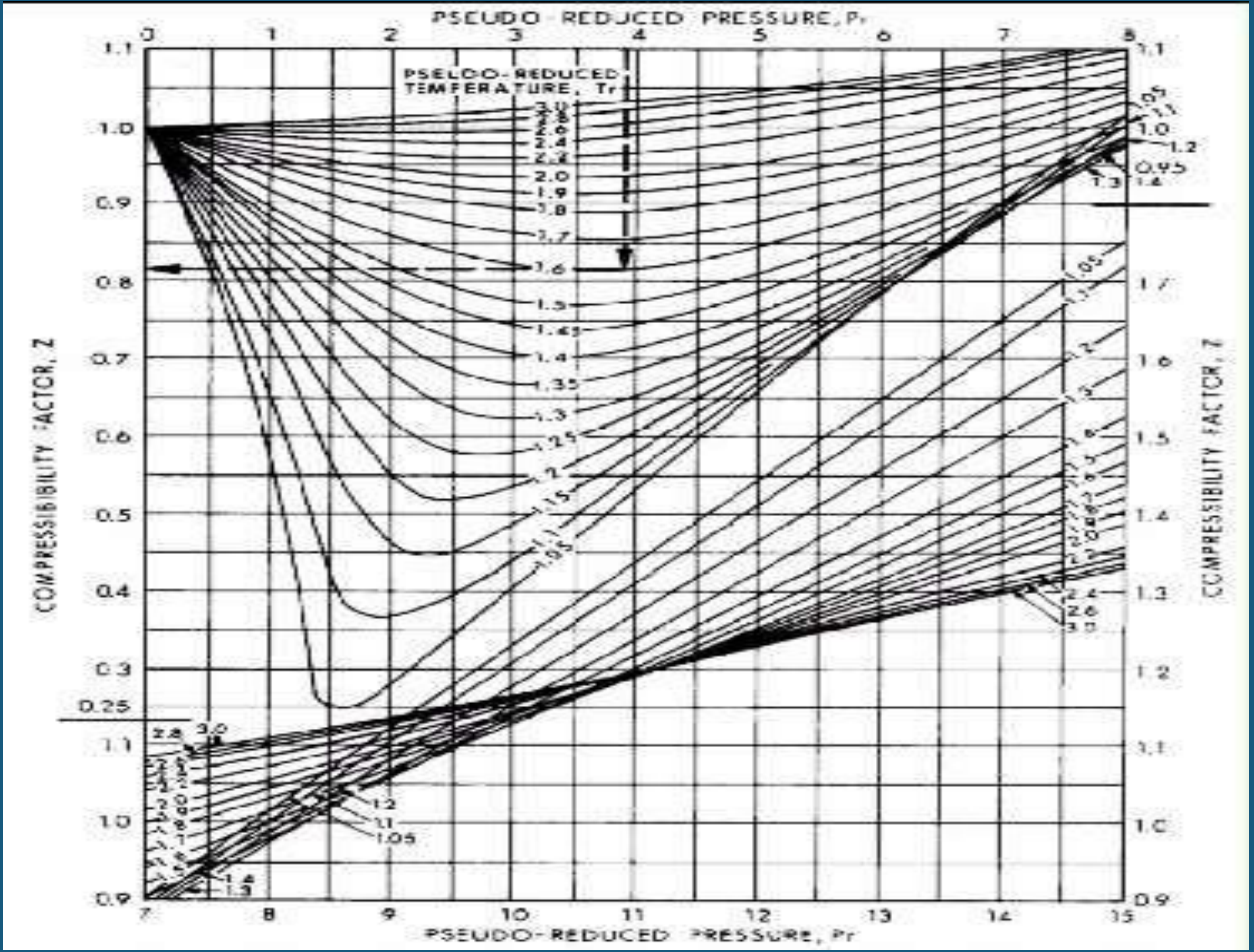


Compressibility Factor

- P_R = (reduced pressure)
- T_R = (reduced temperature)
- $P_R = \frac{P}{P_c}$
- $T_R = \frac{T}{T_c}$
- (What about gas mixture?)

- Pseudo-reduced pressure (P_{pc})
- Pseudo-reduced temperature (T_{pc})
- $P_{pc} = \sum_{i=1}^{n} y_i P_{ci}$ $\quad P_{pr} = \frac{P}{P_{pc}}$
- $T_{pc} = \sum_{i=1}^{n} y_i T_{ci}$ $\quad T_{pr} = \frac{T}{T_{pc}}$

Compressibility Factor



Compressibility Factor

- Example:

A gas reservoir has the following gas composition: the initial reservoir pressure and temperature are 3000 psia and 180°F, respectively.

Component	y_i
CO_2	0.02
N_2	0.01
C_1	0.85
C_2	0.04
C_3	0.03
$i - C_4$	0.03
$n - C_4$	0.02

Calculate the gas compressibility factor under initial reservoir conditions.

Compressibility Factor

- Solution:

Component	y_i	T_{ci}, °R	y_iT_{ci}	p_{ci}	$y_i p_{ci}$
CO_2	0.02	547.91	10.96	1071	21.42
N_2	0.01	227.49	2.27	493.1	4.93
C_1	0.85	343.33	291.83	666.4	566.44
C_2	0.04	549.92	22.00	706.5	28.26
C_3	0.03	666.06	19.98	616.4	18.48
$i - C_4$	0.03	734.46	22.03	527.9	15.84
$n - C_4$	0.02	765.62	15.31	550.6	11.01
			$T_{pc} = 383.38$		$p_{pc} = 666.38$

- $P_{pr} = \frac{3000}{666.38} = 4.5$
- $T_{pr} = \frac{(180+460)}{383.38} = 1.67$
- $Z = 0.85$

Gas Density

- $PV = ZnRT$
- $\rho = \frac{W}{V}$
- $n = \frac{w}{M_w}$
- $PV = \frac{w}{M_w} ZRT$
- $PM_w = \frac{w}{V} ZRT = \rho ZRT$
- $\rho = \frac{PM_w}{ZRT}$
- Mixture?

- $\rho_g = \frac{PM_a}{ZRT}$
- $M_a = \sum_{i=1}^{n} y_i M_i$

Gas Density

- *Example:*
- $\rho_g = \frac{PM_a}{ZRT}$
- $M_a = \sum_{i=1}^{n} y_i M_i$
- $M_a = 20.23$
- $\rho_g = \frac{(3000)(20.23)}{(0.85)(10.73)(64)} = 10.4\ lb/ft^3$

Critical Properties Correlation

- Natural gas systems
- $T_{pc} = 168 + 325\,\gamma_g - 12.5\,\gamma_g{}^2$
- $P_{pc} = 677 + 15.0\,\gamma_g - 37.5\,\gamma_g{}^2$

- Condensate systems
- $T_{pc} = 187 + 330\,\gamma_g - 71.5\,\gamma_g{}^2$
- $P_{pc} = 706 - 51.7\,\gamma_g - 11.1\,\gamma_g{}^2$

Critical Properties Correlation