Appendix 'A'

CORRELATIONS FOR THERMODYNAMIC PROPERTIES OF R 290 AND R 600A

Reynolds* also gives correlations for R 290 and R 600a which are as follows.

Vapour Pressure Correlation

$$\text{In } P_s/P_c = \left(\frac{T_c}{T_c} = 1\right)\sum_{-i=1}^{8} P_i\left(\frac{T_s}{T_P} = 1\right)^{i-1} \qquad \text{(i)}$$

The constants are given in the table below:

Constants	Propane	Isobutene
P_1	-6.230993	-6.3016457
P_2	-44226860×10^{-1}	2.1880736×10^{-1}
P_3	-1.8839624	-1.1288158
P_4	3.6383362×10^{-1}	2.2391095
P_5	1.5177354×10^{1}	1.065363
P_6	1.1216551×10^{2}	9.3322720
P_7	2.7635840×10^{2}	2.4836848×10^{1}
P_8	2.358535×10^{2}	3.7187854×10^{1}
P_p	300	300
P_c	4.2359300×10^{6}	3.6845470×10^{6}

From Eq. (i) we obtain

$$\left[\frac{d\,P_s}{d\,T_s}\right] = P_s\left[-\frac{T_c}{T_s^2}\sum_{i=1}^{8} P_i\left[\frac{T_s}{T_p}-1\right]^{i-1} + \left[\frac{T_c}{T_s}-1\right]\frac{1}{T_P}\left[\frac{T_s}{T_P}-1\right]^{i-2}\sum_{i=1}^{8}(i-1)\,P_i\right] \qquad \text{(ii)}$$

Equation of State and Vapour Phase Enthalpy & Entropy

Reynolds has used the following equation of state for both R 290 and R 600a.

$$P = \rho RT + \left(E_1RT - E_2 - \frac{E_3}{T^2} + \frac{E_4}{T^3} - \frac{E_5}{T^4}\right)\rho^2$$
$$+\left(b\ RT - a - \frac{d}{T}\right)\rho^3 + \alpha\left(a + \frac{d}{T}\right)\rho^6 \qquad \text{(iii)}$$
$$+ c\frac{\rho^3}{T^2}\left(1+\gamma\rho^2\right)e^{-\gamma\rho^2}$$

where P is in Pa, and ρ is in kg/m^3.

The constant for the two refrigerants are given in the table below :

Constants	**Propane**	**Isobutene**
R	1.887326×10^2	1.430797×10^{2}`
E_1	1.366892×10^{-3}	2.018128×10^{-3}
E_2	2.579108×10^2	2.964140×10^2
E_3	3.401044×10^7	2.489763×10^7
E_4	1.076728×10^9	1.163672×10^9
E_5	3.375879×10^{10}	6.371519×10^{10}
b	1.096523×10^{-5}	9.906333×10^{-6}

a	7.856721×10^{-1}	4.100261×10^{-1}
d	1.639769×10^{2}	1.029360×10^{2}
c	1.661103×10^{5}	1.072632×10^{5}
α	5.728034×10^{-9}	5.253972×10^{-9}
γ	9.157270×10^{-6}	8.208363×10^{-6}

From Eq. (iii) we obtain,

$$\left(\frac{dP}{dT}\right)_\rho = \rho R + \rho^2\left[E_1 R + \frac{E_3}{T^3} - \frac{E_4}{T^4} + \frac{E_5}{T^5}\right] + \rho^3\left[bR + \frac{d}{T^2}\right]$$

$$- \frac{\alpha\rho^6 d}{T^2} - \frac{2c\rho^3\left(1+\gamma\rho^2\right)e^{-\gamma\rho^2}}{} \qquad \text{(iv)}$$

Substituting from the above, we obtain the following expressions for the vapour phase enthalpies and entropies of R 290 and R 600a.

$$h = h_o + P\nu - RT_0 + \int_{T_o}^{T} \left(C_p^o - R\right)dT$$

$$+\rho\left[\left(E_1 R + \frac{E_3}{T^3} - \frac{E_4}{T^4} + \frac{E_5}{T^5}\right) - \left(E_1 RT - E_2 - \frac{E_3}{T^2} - \frac{E_4}{T^3} + \frac{E_5}{T^4}\right)\right]$$

$$-\frac{\rho^2}{2}a - \frac{\rho^5}{5}\left[\frac{\alpha d}{T} + \frac{\alpha d}{T^2}\right] - \frac{3c\, e^{-\gamma\rho^2}}{T^2\gamma}(\rho - 1)$$

$$-\frac{3c}{T^2}\left(1 - e^{-\gamma\rho^2}\right) - \frac{\rho^2 e^{-\gamma\rho^2}}{2\gamma} \qquad \text{(v)}$$

$$s = s_0 + \int_{T_0}^{T} \frac{dT}{T} + R\ \text{In}\left[\frac{RT\rho}{P_0}\right] - \rho\left[E_1 R + \frac{2E_3}{T^3} - \frac{3E_4}{T^4} + \frac{4E_5}{T^5}\right]$$

$$-\frac{\rho^2}{2}\left[bR+\frac{d}{T^2}\right]+\frac{\rho^5\alpha d}{5T^2}-\frac{2ce^{-\gamma\rho^2}}{T^3\gamma}(\rho+1) \qquad \text{(vi)}$$

$$+\frac{2c}{\gamma\, T^3}\left(1-e^{-\gamma\rho^2}\right)-\frac{c\rho^2 e^{-\gamma\rho^2}}{\gamma\, T^3}$$

Correlation for Saturated Liquid Density

$$\rho_L=\sum_{i=1}^{6} D_i T_{r1}^{(i-1)/3} \qquad \text{(vii)}$$

Where ρ_L is in kg/m^3, and

$$T_{r1}=1-\frac{T}{T_c}$$

and the constants are given in the table below :

Constants	**Propane**	**Isobutene**
D_1	1.9738193×10^2	1.9450561×10^2
D_2	-2.1307184×10^1	-9.1725345×10^1
D_3	3.3522024×10^3	2.4446128×10^3
D_4	-7.7040243×10^3	-2.7219989×10^3
D_5	-7.5224059×10^3	1.9324597×10^2
D_6	-2.5663363×10^3	8.7037158×10^2

Zero pressure Constant Volume Specific Heat

$$C_v^o=\sum_{i=1}^{6} C_{vi} T^{\,i-2} \qquad \text{(viii)}$$

Constants	Propane	Isobutene
C_{v1}	2.0582170×10^{5}	1.7563902×10^{5}
C_{v2}	-1.9109547×10^{3}	-1.7524300×10^{3}
C_{v3}	1.1622054×10^{1}	1.1642389×10^{1}
C_{v4}	$-9.7951510 \times 10^{-3}$	$-1.0197170 \times 10^{-2}$
C_{v5}	4.5167026×10^{-6}	4.9006615×10^{-6}
C_{v6}	$-8.6345035 \times 10^{-10}$	$-9.8234416 \times 10^{-10}$
u_0	4.2027216×10^{5}	3.9342075×10^{5}
s_0	2.1673997×10^{3}	1.8189390×10^{3}

(e)