The Thermodynamics of Linear Fluids and Fluid Mixtures by Pekař & Samohýl

Page 236, equation (4.427)

Making partial derivative of definition (4.86) gives:

$$\frac{\partial \hat{f}_{\alpha}}{\partial \rho_{\alpha}} = \frac{\partial \hat{u}_{\alpha}}{\partial \rho_{\alpha}} - T \frac{\partial \hat{s}_{\alpha}}{\partial \rho_{\alpha}}, \qquad \alpha = 1, ..., n.$$
(1)

From (4.426) we get:

$$\frac{\partial \hat{s}_{\alpha}}{\partial \rho_{\alpha}} = -\frac{\partial}{\partial \rho_{\alpha}} \left(\frac{\partial \hat{f}_{\alpha}}{\partial T} \right) = -\frac{\partial}{\partial T} \left(\frac{\partial \hat{f}_{\alpha}}{\partial \rho_{\alpha}} \right) = -\frac{\partial}{\partial T} \left(\frac{RT}{M_{\alpha}\rho_{\alpha}} \right) = -\frac{R}{M_{\alpha}\rho_{\alpha}}, \qquad \alpha = 1, ..., n$$
(2)

where (4.429) was used in the last but one equality. Substituting (4.429) and (2) into (1) gives:

$$\frac{RT}{M_{\alpha}\rho_{\alpha}} = \frac{\partial \hat{u}_{\alpha}}{\partial \rho_{\alpha}} + \frac{RT}{M_{\alpha}\rho_{\alpha}} \quad \Rightarrow \quad \frac{\partial \hat{u}_{\alpha}}{\partial \rho_{\alpha}} = 0, \qquad \alpha = 1, ..., n.$$

Consequently, $\hat{u}_{\alpha}(T, \rho_{\gamma})$ simplifies to $\hat{u}_{\alpha}(T)$ – cf. also (4.86), (4.413), and (4.426).