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Further Comments on "Combined Forced and Free Convective Flow in a Vertical Porous Channel: The Effects of Viscous Dissipation and Pressure Work"

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Abstract This note is concerned with the assertion of Barletta and Nield (2009a) that "*a fluid with a thermal expansion coefficient greater than that of a perfect gas* $\left(\beta > \beta_{\text{perfect gas}}\right)$ is of marginal or no interest in the framework of convection in porous media", and that for a remark of Magyari (Transp. Porous Media, 2009) about the forced convection eigenflow solutions, the circumstance $\beta > \beta_{\text{perfect gas}}$ does not represent "*a sound physical basis*". Here, it is shown, however, that these assertions are in contradiction with the experimentally measured values of β for important technical fluids as e.g., air, nitrogen, carbon dioxide, and ammonia where, in the temperature range between −20 and +100°C, just the inequality $\beta > \beta_{\text{perfect gas}}$ holds.

Keywords Mixed convection · Laminar flow · Porous media · Viscous dissipation · Pressure work · Analytical solution

The condition for the existence of eigenflow solutions in the forced convection limit $R = 0$ is the inequality $\beta(T) > \beta_{\text{perfect gas}} = 1/T$. As illustrated in Fig. 1, this condition is satisfied for some important technical fluids as ammonia and carbon dioxide in a significant temperature range. The lower the temperature, the larger β compared to $\beta_{\text{perfect gas}}$. These plots are based on the data of Table B4, page 646 (ammonia) and Table B5 page, 647 (carbon dioxide) of Baehr and Stephan (1994). Moreover, according to Table B1, page 642 and Table B6, page 648 of Baehr and Stephan (1994), the condition $\beta > \beta_{\text{perfect gas}}$ is also satisfied for dry air and nitrogen, whose β-curves would lie in Fig. 1 below of $\beta_{\text{carbon dioxide}}$ but above of $\beta_{\text{perfect gas}}$. Therefore, we may summarize that at $p = 1$ *bar* in the whole temperature range $250\,\text{K} \leq T \leq 375\,\text{K}$ the following inequalities hold:

$$\beta_{\text{ammonia}}(T) > \beta_{\text{carbon dioxide}}(T) > \beta_{\text{air}}(T) \geq \beta_{\text{nitrogen}}(T) > \beta_{\text{perfect gas}} = 1/T \qquad (1)$$

We emphasize here that for the existence of the eigenflow solutions in the forced convection limit $R = 0$, it is not important at all how much $\beta(T)$ exceeds the corresponding value

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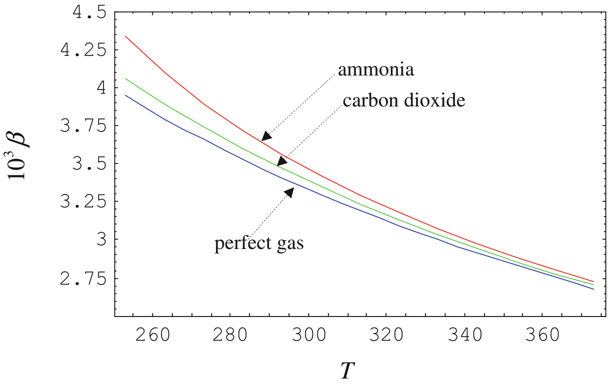

Fig. 1 Variation of the thermal expansion coefficient $\beta[K^{-1}]$ of a perfect gas (*blue curve*), the carbon dioxide (*green curve*) and the ammonia (*red curve*) in the temperature range $250\,\mathrm{K} \leq T \leq 375\,\mathrm{K}$ at the constant pressure of $p = 1\,bar$. It is clearly seen that everywhere in this interval the inequality $\beta_{\text{ammonia}} > \beta_{\text{carbon dioxide}} > \beta_{\text{perfect gas}}$ holds

of $\beta_{\text{perfect gas}}$. The only relevant criterion is the inequality $\beta > \beta_{\text{perfect gas}}$. Attributes such as "*of marginal interest*" and "*significant violation*" (of the inequality $\beta \leq \beta_{\text{perfect gas}}$) do not weaken this basic criterion in any way. They only make the arguments fuzzy and even misleading. Consequently, the result of Barletta and Nield (2009b) that a mixed convection eigenflow solution can only exist for $R > 0.01$, is and remains an artifact: a consequence of their choice of the parameter values $\gamma = 50$ and $\varepsilon = 0.01$ with the property $\beta < \beta_{\text{perfect gas}}$ (which is opposite to the message of Fig. 1 and of Eq. 1).

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