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Professor Wallis and Professor Ransom:

The correct linear solution for the void fraction in TRACE is outlined in these notes. This is a method to correctly obtain an approximate value for the void. Note that the void fraction does not in fact satisfy any linear equations; only non-linear.

Linear solution for the void fraction

The four equations that provide the correct solution for the void, and the new-time liquid and vapor temperature and the pressure are

$$\begin{aligned} &<(1-\alpha_v)\rho_l(P,T_l)>-(1-\alpha_v)\rho_l(P,T_l)=0 \\ &<\alpha_v\rho_v(P,T_v)>-\alpha_v\rho_v(P,T_v)=0 \\ &<(1-\alpha_v)\rho_l(P,T_l)e_l(P,T_l)>-(1-\alpha_v)\rho_l(P,T_l)e_l(P,T_l)=0 \\ &<\alpha_v\rho_v(P,T_v)e_v(P,T_v)>-\alpha_v\rho_v(P,T_v)e_v(P,T_v)=0 \end{aligned} \tag{1.1}$$

Four implicit non-linear equations for the four unknowns α_v, P, T_l, T_v. As stated in the manual, these equations are not solved for the final new-time values of these quantities. Instead they are linearized, as they would be for almost all numerical solution methods, and the results from the first iterate for the void fraction is retained and used in subsequent calculations.

The correct linear approximation, in contrast to whatever the method in TRACE might be producing, is

$$\begin{aligned} \alpha^{n+1} \cong \alpha^n &+ \left(\frac{\partial\alpha}{\partial(1-\alpha)\rho_l}\right)\left(\Delta\overline{(1-\alpha)\rho_l}\right)^{n+1} + \left(\frac{\partial\alpha}{\partial\alpha\rho_v}\right)\left(\Delta\overline{\alpha\rho_v}\right)^{n+1} \\ &+ \left(\frac{\partial\alpha}{\partial(1-\alpha)\rho e_l}\right)\left(\Delta\overline{(1-\alpha)\rho e_l}\right)^{n+1} + \left(\frac{\partial\alpha}{\partial\alpha\rho e_v}\right)\left(\Delta\overline{\alpha\rho e_v}\right)^{n+1} \end{aligned} \tag{1.2}$$

where the superscript $n+1$ means the difference between the current and previous time level values. These quantities are the solution variables in one of the SETS steps in TRACE.

The partial derivatives in Equation (1.2) can only be obtained by application of implicit function theory to the system (1.1). I do not intend to go through the extensive algebraic work to get these in these notes. It is a simple and straightforward standard method. Although, it has taken me some time to come up with how to correctly get a linear solution for the void fraction.

 GT-350

The other thermodynamic state quantities can be est[illegible] process.

So at this time there are at least three ways to calculate the void fraction in the TRACE code: (1) the incorrect method presently in the code, (2) the linear method mentioned above, and (3) complete and correct solution of the non-linear system of (1.1). In the absence of any theoretical basis for (1) it seems that only (2) or (3) should in fact be considered.

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