# Derivation of Densities and Heat Capacities From Speed of Sound Data for R-134a

T.C. Dayton, S.W. Beyerlein, and A.R.H. Goodwin
*Center for Applied Thermodynamic Studies*
*University of Idaho*
*Moscow, ID 83844-1011 USA*

Accurate densities, sound speeds, and heat capacities are essential for selecting environmentally-safe refrigerants. Independent measurements of all quantities can lead to systematic errors, for example, those arising from inconsistent material purity or measurements, temperature and pressure. An alternative approach is to derive these quantities solely from speed of sound measurements. Speed of sound data ($u$, T, P) are independent of the amount of substance and consequently offer a favorable route for obtaining density ($\rho$), isochoric heat capacity ($C_v$) and isobaric heat capacity ($C_p$).

Two sets of differential equations have been examined for transforming speed of sound data into all other thermodynamic properties. In one set of equations, temperature and pressure are the independent variables. In the other set of equations temperature and density are the independent variables. Both sets of equations are analyzed for 1,1,1,2-tetrafluoroethane (R-134a) with data calculated from an accurate equation of state. Data analyzed cover the temperature range 340 to 500 K at densities less than 8 mol/dm$^3$ . This corresponds to reduced temperatures between 0.8 and 1.3 and reduced pressures less than 6.0. Each set of equations was evaluated with respect to interpolation step size, accuracy of initial conditions, presence of errors in the data, and proximity to the vapor pressure. The isochoric technique was found to be more accurate than the isothermal technique, especially above the critical pressure. The estimated accuracy of thermodynamic properties obtained with the isochoric technique is ± 0.1% in density and ± 1% in heat capacity. These uncertainties are equivalent to those associated with the most recent equation of state for R-134a.