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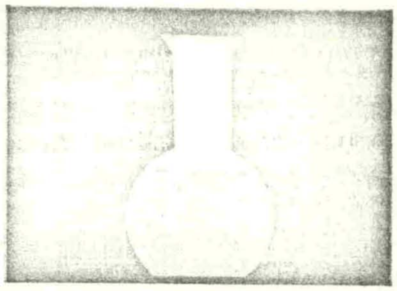
Estimating Thermophysical Properties of Liquids



Part 9—Compressibility, Velocity of Sound

Rough engineering estimates of isothermal and adiabatic compressibilities and velocity of sound can be obtained with the not-too-reliable techniques available.

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We continue our series on the estimation of thermophysical properties of liquids with a consideration of three closely related and useful properties: isothermal and adiabatic compressibilities (α_T and α_a, respectively), and the velocity of sound u.

The techniques evaluated here for the calculation of these properties are relatively simple and yield rough engineering estimates. However, caution should be exercised so that an unwarranted degree of reliability will not be ascribed to the results.

* To meet the authors, see *Chem. Eng.*, Oct. 7, 1968, p. 154.

Nomenclature	
A, B, C	Constants
c_p	Heat capacity at constant pressure, cal./(g.-mole) (°K.)
c_v	Heat capacity at constant volume, cal./(g.-mole) (°K.)
M	Molecular weight
p^*	Vapor pressure, atm.
T	Temperature, °K.
T_c	Critical temperature, °K.
T_r	Reduced temperature, $T_r = T/T_c$
u	Velocity of sound, cm./sec.
V	Molar volume, cc./(g.-mole)
Z	Compressibility factor, dimensionless
α_a	Adiabatic compressibility, sq.cm./dyne
α_T	Isothermal compressibility, sq.cm./dyne
β	Constant
λ	Latent heat of vaporization, cal./g.
ρ	Density, g./cc.
σ	Surface tension, dynes/cm.

Thermodynamically, the three properties are defined, respectively, as:

$$\alpha_T = -(1/V)\,(\partial V/\partial P)_T \qquad (1)$$

$$\alpha_a = -(1/V)\,(\partial V/\partial P)_s \qquad (2)$$

$$u = (\partial P/\partial \rho)_s^{1/2} \qquad (3)$$

where the subscript s refers to an isentropic process.

The first two equations represent exact thermodynamic definitions. The definition of the velocity of sound (Eq. 3), however, is subject to certain restrictions such as the assumption of small pressure and density differences across the sound wave. In addition, it must be assumed that the change in state of the fluid across the wave front (resulting from such factors as the pressure and density differences just mentioned) is essentially adiabatic, and that—if there is no internal friction or viscosity factor—the process is also reversible and, therefore, isentropic.

One very interesting aspect of the compressibilities is the relationship of the compressibility ratio, α_T/α_a, to the more familiar specific-heat ratio. It is not difficult to show that:

$$C_p/C_v = (\partial P/\partial V)_s/(\partial P/\partial V)_T = \alpha_T/\alpha_a \qquad (4)$$

Combining Eq. (2) and (3):

$$\alpha_a = V/u^2, \quad \text{and} \qquad (5)$$

$$C_p/C_v = \alpha_T u^2/V \qquad (6)$$

Further manipulation of these equations yields other useful relationships between these values.