JOURNAL OF THERMOPHYSICS AND HEAT TRANSFER
Vol. 23, No. 4, October–December 2009

Thermal Conductivity of Liquid Hydrazine (N_2H_4) at 293.2 Kelvin and 0.101 to 2.068 Megapascals

J. D. DeSain* and B. B. Brady
The Aerospace Corporation, El Segundo, California 90245-4691

DOI: 10.2514/1.38775

The thermal conductivity of liquid hydrazine was measured by the steady-state hot-wire method at 293.2 K and 0.101 MPa. Eight pure organic liquids were used as reference liquids to calibrate the experimental apparatus. The thermal conductivity was determined to be $\lambda = 0.32 \pm 0.03\ \mathrm{W \cdot m^{-1} \cdot K^{-1}}$. The present measurement is in agreement with one recent measurement. The present measurement disagrees with the most recent measurement as well as several previous measurements and estimation methods. The thermal conductivity was determined to change very little over the pressure range of 0.101 to 2.068 MPa. The present observed pressure dependence is in agreement with one previous pressure dependence measurement. The speed of sound in liquid hydrazine was measured to be $2092 \pm 12\ \mathrm{m \cdot s^{-1}}$, in agreement with previous measurements. There are large inaccuracies obtained when estimating the thermal conductivity of hydrazine by using standard estimation methods that use speed-of-sound data.

Nomenclature

c_N = speed of sound, $\mathrm{m\,s^{-1}}$
I_c = constant current, A
k = Boltzmann constant, $1.38066 \times 10^{-23}\ \mathrm{J \cdot K^{-1}}$
L = path length, m
N_A = Avogadro constant, $6.02214 \times 10^{-23}\ \mathrm{mol^{-1}}$
P = pressure, Pa
q = heat flux, $\mathrm{J \cdot m^{-2} \cdot s^{-1}}$
R = resistance, Ω
R_c = gas constant
T = temperature, K
V_f = voltage, V
V_η = molar volume, $\mathrm{m^3 \cdot mol^{-1}}$
α, β = thermal conductivity constants of measurement cell
Δf = liquid resonance-frequency difference, Hz
λ = thermal conductivity, $\mathrm{W \cdot m^{-1} \cdot K^{-1}}$
υ = specific volume, $\mathrm{m^3 \cdot kg^{-1}}$
υ_c = critical volume, $\mathrm{m^3 \cdot kg^{-1}}$

I. Introduction

HYDRAZINE (N_2H_4) is a propellant often used in propulsion systems for orbital maneuvering on manned and unmanned spacecraft. The thermal properties of pure liquid hydrazine are of major interest when designing processing equipment, spacecraft, and propulsion engines. The thermal conductivity is an indispensable parameter in engineering work that involves heat transfer applications. It is also important to understand the pressure dependence of the thermal properties of hydrazine, because it is usually stored under pressure in orbit. Despite the importance of this thermal property, there is very little agreement in the literature among reliable data sources. The current literature disagrees by an order of magnitude from the first experimental measurements to the most recent measurements on the thermal conductivity of liquid hydrazine [1–5].

One problem measuring pure hydrazine is that hydrazine is hydroscopic and older samples could have potentially contained other manufacturing impurities such as aniline. These impurities could potentially have major effects on the measured thermal conductivity of hydrazine. This is particularly true of water and ammonia impurities, as liquid water and liquid ammonia have large thermal conductivities compared with most liquids at 293.15 K and 0.101 MPa. Table 1 lists the several previous sources for the thermal conductivity value for liquid hydrazine in various solvents [1–5]. The thermal conductivity of hydrazine was determined previously by the Ralph M. Parsons Corporation [1]; however, the report is now out of print and there are few details on how the value was obtained. Bachmaier [2] measured the thermal conductivity of hydrazine/methanol mixtures. Once again, there was very little detail in the report on how this value was obtained or the purity of hydrazine used in the experiment. Safarov and Zaripova [3] measured the thermal conductivity of hydrazine–water mixtures as a function of temperature and pressure using a cylindrical bicalorimeter. They obtained a smaller thermal conductivity than the two older measurements for 90% hydrazine in water ($\lambda = 0.395\ \mathrm{W \cdot m^{-1} \cdot K^{-1}}$) at 293 K. Their extrapolated 100% hydrazine value was $\lambda = 0.328\ \mathrm{W \cdot m^{-1} \cdot K^{-1}}$ at 293 K and 0.101 MPa. The Safarov and Zaripova value agrees with the value in the most recent *Chemical Properties Handbook* [4] ($\lambda = 0.4008–1.5493 \times 10^{-4}T–4.8625 \times 10^{-7}T^2$, where λ is in $\mathrm{W \cdot m^{-1} \cdot K^{-1}}$ and T is in Kelvin) at 293 K ($\lambda = 0.314\ \mathrm{W \cdot m^{-1} \cdot K^{-1}}$). There is no reference in the handbook regarding the origin of the thermal conductivity value other than that it was based on unspecified experimental and calculated values. The most recent measurement from Grebenkov et al. [5] is an order of magnitude smaller than the older measurements at 295 K and 0.101 MPa ($\lambda = 0.0499\ \mathrm{W \cdot m^{-1} \cdot K^{-1}}$). This value is on the low end of thermal conductivity of most measured liquids. Grebenkov et al. used a steady-state hot-wire method with anhydrous hydrazine.

For most pure liquids, the thermal conductivity can be estimated by using the modified Bridgman equation [6,7]:

$$\lambda = 2.8 \left(\frac{N_A}{V_\eta} \right)^{2/3} k c_N \tag{1}$$

In Eq. (1), N_A is Avogadro's number, V_η is the molar volume, k is Boltzmann's constant, and C_N is the speed of sound in the fluid. For liquid water, the speed of sound is $1496.70\ \mathrm{m \cdot s^{-1}}$ at 298.15 K. The speeds of sound in hydrazine, monomethyl hydrazine (MMH), and unsymmetric dimethyl hydrazine (UDMH) were previously measured by Kretschmar, as discussed in [8–11] [$c_N =$ $2074\ \mathrm{m \cdot s^{-1}}$ (N_2H_4), $1548\ \mathrm{m \cdot s^{-1}}$ (MMH), and $1247\ \mathrm{m \cdot s^{-1}}$ (UDMH)], at 298.15 K . The thermal conductivity of hydrazine estimated by the Bridgman equation is $0.569\ \mathrm{W \cdot m^{-1} \cdot K^{-1}}$ at

---

Received 27 May 2008; accepted for publication 5 November 2008.

*2350 East El Segundo Boulevard, Mail Stop 2-341; John.D.DeSain@aero.org.